(12) INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(51) **International Patent Classification⁷:** C08J 9/16, 9/24 // C08L 23/10

(21) **International Application Number:** PCT/JP02/11391

(22) **International Filing Date:** 31 October 2002 (31.10.2002)

(25) **Filing Language:** English

(26) **Publication Language:** English

(30) **Priority Data:**

2001-336831	1 November 2001 (01.11.2001)	JP
2001-401250	28 December 2001 (28.12.2001)	JP
2002-054693	28 February 2002 (28.02.2002)	JP

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(81) **Designated States** (national): AE, AG, AL, AM, AT, AU, AZ, BA, BB, BG, BR, BY, BZ, CA, CH, CN, CO, CR, CU, CZ, DE, DK, DM, DZ, EC, EE, ES, FI, GB, GD, GE, GH, GM, HR, HU, ID, IL, IN, IS, KE, KG, KP, KR, KZ, LC, LK, LR, LS, LT, LU, LV, MA, MD, MG, MK, MN, MW, MX, MZ, NO, NZ, OM, PH, PL, PT, RO, RU, SD, SE, SG, SI, SK, SL, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, YU, ZA, ZM, ZW.

(84) **Designated States** (regional): ARIPO patent (GH, GM, KE, LS, MW, MZ, SD, SL, SZ, TZ, UG, ZM, ZW), Eurasian patent (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European patent (AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE, SK, TR), OAPI patent (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, ML, MR, NE, SN, TD, TG).

Published:
— without international search report and to be republished upon receipt of that report

For two-letter codes and other abbreviations, refer to the "Guidance Notes on Codes and Abbreviations" appearing at the beginning of each regular issue of the PCT Gazette.

(54) **Title:** PROCESS OF PRODUCING FOAMED MOLDING FROM EXPANDED POLYPROPYLENE RESIN BEADS AND PROCESS OF PRODUCING EXPANDED POLYPROPYLENE RESIN BEADS

(57) **Abstract:** A process of producing a foamed molding, wherein expanded, substantially non-crosslinked polypropylene-based resin beads are heated in a mold to fuse-bond the beads together into a unitary body. Each of the expanded beads has been surface-modified with an organic peroxide.

1

DESCRIPTION

Process of Producing Foamed Molding from
Expanded Polypropylene Resin Beads and Process of
Producing Expanded Polypropylene Resin Beads

TECHNICAL FIELD

This invention relates to a process of producing a
molded article from expanded polypropylene resin beads and
to a process of producing expanded polypropylene resin
beads.

BACKGROUND ART

A polypropylene resin is now increasingly utilized
in various fields because of excellent mechanical
strengths, heat resistance, machinability, cost balance,
combustibility and recyclability thereof. Foamed, non-
crosslinked resin moldings of a base resin including a
polypropylene resin (hereinafter referred to simply as "PP
moldings"), which retain the above excellent properties
and which have excellent additional characteristics such
as cushioning property and heat resistance, are thus
utilized for various applications as packaging materials,
construction materials, heat insulation materials, etc.

Recently, there is an increasing demand for PP
moldings having higher rigidity and lighter weight than
the conventional ones. For example, in the field of
vehicles such as automobiles, PP moldings have been used
in various parts such as bumper cores, door pats, pillars,
tool boxes and floor mats. In view of protection of
environment and saving of energy, light weight and·high
rigidity PP moldings retaining excellent cushioning and
shock absorbing properties are desired. In the field of
containers and boxes for storing and transporting foods
such as fish, molded polystyrene foams have been hitherto
used. Because of inferior shock and heat resistance,

2

however, molded polystyrene foams are not suitably reused. Therefore, the need for light weight and high rigidity PP moldings is also increasing in this field.

One known method for improving rigidity of PP
5   moldings produced by molding expanded, substantially non-crosslinked resin beads of a base resin including a polypropylene resin (hereinafter referred to as "expanded PP beads") in a mold is to use a high rigidity polypropylene resin as a raw material. Thus, a propylene
10   homopolymer or a propylene copolymer containing a reduced content of a comonomer such as butene or ethylene has been used. Such a high rigidity polypropylene resin, however, has a high melting point and requires a high temperature for molding. When steam is used for molding, it is
15   necessary to use high pressure steam and, therefore, to use a special molding device having a high pressure resistance, in order to attain sufficient melt adhesion between the expanded PP beads.

Another known method for improving rigidity of PP
20   moldings is to use expanded PP beads which show, in a DSC curve thereof, a high temperature peak of a large area in addition to an intrinsic peak which is present in a lower temperature side of the high temperature peak and is inherent to the polypropylene resin. In this case, too,
25   it is necessary to use high pressure steam and, therefore, to use a special molding device having a high pressure resistance, in order to attain sufficient melt adhesion between the expanded PP beads.

30   DISCLOSURE OF THE INVENTION

It is an object of the present invention to provide a process capable of producing a PP molding having high rigidity (high compression strength) and high adhesion between beads by molding expanded PP beads in a mold using
35   steam at a relatively low temperature. Another object of

the present invention is to provide a process capable of
producing a PP molding having excellent weatherability,
heat resistance and recyclability. It is a further object
of the present invention to provide an economical process

5   for producing expanded PP beads.

In accomplishing the foregoing objects, there is
provided in accordance with one aspect of the present
invention a process of producing a foamed molding,
comprising the steps of:

10   (a) dispersing substantially non-crosslinked resin
particles of a base resin including a polypropylene resin
in a dispersing medium containing an organic peroxide to
obtain a dispersion;

            (b) maintaining said dispersion at a temperature

15   lower than the melting point of said base resin but
sufficient to decompose said organic peroxide, thereby
obtaining substantially non-crosslinked, surface-modified
resin particles;

            (c) foaming and expanding said non-crosslinked,

20   surface-modified resin particles using a blowing agent to
obtain expanded, substantially non-crosslinked resin
beads;

            (d) filling said expanded resin beads in a mold
cavity;

25   (e) heating said expanded resin beads in said mold
cavity to fuse-bond said expanded resin beads together
into a unitary body; and

            (f) cooling said unitary body.

In another aspect, the present invention provides a

30   process of producing a foamed molding, comprising the
steps of:

            (a) filling expanded, substantially non-crosslinked
resin beads of a base resin including a polypropylene
resin in a mold cavity, said expanded resin beads having a

35   surface region and an inside region surrounded by said

4

surface region, wherein each of said surface and inside
regions shows a high temperature endothermic peak, in a
DSC curve thereof, in addition to an intrinsic endothermic
peak located at a lower temperature side of said high
5   temperature peak, and wherein said high temperature
endothermic peaks of said surface region and said inside
region have heat of fusion of Hs and Hi, respectively, and
wherein Hs and Hi have the following relationship:
Hs < 0.86×Hi
10   (b) heating said expanded resin beads in said mold
cavity to fuse-bond said expanded resin beads together
into a unitary body; and
            (c) cooling said unitary body.
        The present invention also provides a process of
15 producing a foamed molding, comprising the steps of:
            (a) filling expanded, substantially non-crosslinked
resin beads of a base resin including a polypropylene
resin in a mold cavity, said expanded resin beads
exhibiting a high temperature endothermic peak, in a DSC
20 curve thereof, in addition to an intrinsic endothermic
peak located at a lower temperature side of said high
temperature peak, each of said expanded beads having a
surface showing a melt initiation temperature not higher
than the melting point of said base resin,
25   (b) heating said expanded resin beads in said mold
cavity to fuse-bond said expanded resin beads together
into a unitary body; and
            (c) cooling said unitary body.
        The present invention further provides a process of
30 producing a foamed molding, comprising the steps of:
            (a) filling expanded, substantially non-crosslinked
resin beads of a base resin including a polypropylene
resin in a mold cavity, said expanded resin beads
exhibiting a high temperature endothermic peak, in a DSC
35 curve thereof, in addition to an intrinsic endothermic

peak located at a lower temperature side of said high
temperature peak, each of said expanded beads having a
surface having an extrapolated melt initiation temperature,
as measured by micro differential thermoanalysis, not
5   higher than (Tm + 4°C) where Tm is the melting point of
the base resin,

     (b) heating said expanded resin beads in said mold
cavity to fuse-bond said expanded resin beads together
into a unitary body; and

10   (c) cooling said unitary body.

     The present invention further provides a process for
the preparation of expanded resin beads, comprising the
steps of:

     (a) dispersing substantially non-crosslinked resin
15   particles of a base resin including a polypropylene resin
in a dispersing medium containing an organic peroxide to
obtain a first dispersion having a weight ratio of said
resin particles to said dispersing medium of 0.6:1 to
1.3:1;

20   (b) maintaining said dispersion at a temperature
lower than the melting point of said base resin but
sufficient to decompose said organic peroxide, thereby
obtaining substantially non-crosslinked, surface-modified
resin particles dispersed in said dispersing medium;

25   (c) impregnating said surface-modified resin
particles with a blowing agent, while maintaining the
weight ratio of said surface-modified resin particles to
said dispersing medium at 0.5 or less, to obtain a second
dispersion; and

30   (d) reducing the pressure of said second dispersion
to foam and expand said surface-modified resin particles.

     Other objects, features and advantages of the
present invention will become apparent from the detailed
description of the preferred embodiments of the invention
35   which follows, when considered in light of the

accompanying drawings, in which:

FIG. 1 is an initial DSC curve of expanded polypropylene beads;

FIG. 2 is a second time DSC curve of polypropylene resin particles which have not yet been subjected to surface modification and which have been once subjected to DSC measurement; and

FIG. 3 shows µDTA curves obtained by micro differential thermoanalysis of surfaces of expanded PP beads obtained in Example 7 and Comparative Example 5.

FIG. 4 is a schematic illustration of a molding device used in Example 9; and

FIG. 5 shows a µDTA curve obtained by micro differential thermoanalysis of a surface of an expanded PP bead obtained in Example 9.

The expanded PP beads according to the present invention are prepared by expanding substantially non-crosslinked resin particles of a base resin including a polypropylene resin. The term "polypropylene resin" as used herein refers to (1) polypropylene homopolymer, (2) a copolymer of propylene and one or more comonomers having a propylene content of at least 60 mole %, a mixture of two or more of the copolymers (2), or a mixture of the homopolymer (1) and the copolymer (2).

The copolymer may be, for example, ethylene-propylene block copolymers, ethylene-propylene random copolymers, propylene-butene random copolymers or ethylene-propylene-butene random copolymers.

The base resin containing the polypropylene resin as essential component preferably has a melting point of at least 130°C, more preferably at least 135°C, still more preferably at least 145°C, most preferably 158-170°C, for reasons of suitable physical properties of PP molding.

For reasons of heat resistance of PP molding and expansion efficiency in producing expanded particles, the base resin

7

preferably has a melt flow rate (MFR) of 0.3-100 g/10 min,
more preferably 1-90 g/10 min. The MFR herein is as
measured in accordance with the Japanese Industrial
Standard JIS K7210-1976, Test Condition 14.

5   If desired, the base resin may contain one or more
additional resins or one or more elastomers. The amount of
the additional resin or elastomer in the base resin is
preferably no more than 35 parts by weight, more
preferably no more than 25 parts by weight, still more

10   preferably no more than 15 parts by weight, most
preferably no more than 10 parts by weight, per 100 parts
by weight of the polypropylene resin. Examples of the
additional resins include polyethylene resins such as high
density polyethylenes, medium density polyethylenes, low

15   density polyethylenes, linear low density polyethylenes,
linear very low density polyethylenes, ethylene-vinyl
acetate copolymers, ethylene-acrylic acid copolymers,
ethylene-methacrylic copolymers; and polystyrene resins
such as polystyrene and styrene-maleic anhydride

20   copolymers. Examples of elastomers include ethylene-
propylene rubber, ethylene-1-butene rubber, propylene-1-
butene rubber, styrene-butadiene rubber, isoprene rubber,
neoprene rubber, nitrile rubber, styrene-butadiene block
copolymers and hydrogenated products of the above rubbers

25   and copolymers.
       The base resin may also be blended with one or more
additives such as an antioxidant, a UV absorbing agent, a
foam controlling agent, a sterically hindered amine
compound, an antistatic agent, a fire retardant, a metal-

30   deactivator, a pigment, a nucleus agent, a filler, a
stabilizer, a reinforcing material and a lubricant. The
foam controlling agent may be, for example, an inorganic
powder such as zinc borate, talc, calcium carbonate, borax
or aluminum hydroxide.

35   The hindered amine compound (hereinafter referred to

8

as HALS) is a compound containing the following structure
(1):

···(1)
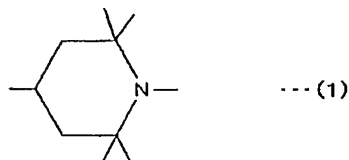
It is preferred that HALS used have a molecular weight of
400-10,000, more preferably 400-5,000, most preferably
2,500-5,000, for reasons of prevention of bleeding thereof
on surfaces of the resin particles and suitable
dispersibility thereof in the resin particles. When HALS
is a mixture of compounds having different molecular
weights, the above "molecular weight" refers to an average
molecular weight as measured by gel permeation
chromatography using polystyrene as a reference. As
compared with known stabilizers for polypropylene resins,
such as phenol compounds, phosphorus compounds and sulfur
compounds, HALS exhibits superior heat resistance and
weatherability.

Specific examples of HALS include dimethyl
succinate-1-(2-hydroxyethyl)-4-hydroxy-2,2,6,6-
tetramethylpiperidine polycondensate, bis(2,2,6,6-
tetramethyl-4-piperidyl)sebacate, poly[{6-(1,1,3,3-
tetramethylbutyl)imino-1,3,5-triazine-2,4-diyl}{2,2,6,6-
tetramethyl-4-piperidyl)imino}hexamethylene{2,2,6,6-
tetramethyl-4-piperidyl)imino}], N,N'-bis(3-
aminopropyl)ethylenediamine-2,4-bis[N-butyl-N-(1,2,2,6,6-
pentamethyl-4-piperidyl)amino]-6-chloro-1,3,5-triazine
condensate, bis(1-octyloxy)-2,2,6,6-tetramethyl-4-
piperidyl)sebacate, bis(1,2,2,6,6-pentamethyl-4-
piperidyl)sebacate, bis(1,2,6,6-pentamethyl-4-piperidyl)-
2-(3,5-di-t-butyl-4-hydroxybenzyl)-2-n-butyl malonate.
HALS is described in detail in SAKAI, Tsuruo, "Development
and Recent Technology of Polymer Additive", edited by CMC
Co., Ltd., published by Disc Co., Ltd., pages 9 and 16,

9

May 29, 1992, the disclosure of which is hereby
incorporated by reference herein.

The amount of HALS is generally 0.01-2 % by weight,
preferably 0.05-1 % by weight, more preferably 0.05-0.5 %
5 by weight, based on the weight of the base resin, for
reasons of improved heat resistance, weatherability and
surface characteristics of the expanded PP beads.

The additive or additives are generally used in an
amount of 20 parts by weight or less, preferably 10 parts
10 by weight or less, more preferably 0.005-5 parts by weight,
per 100 parts by weight of the base resin.

The resin particles used as a raw material for the
production expanded PP beads according to the present
invention may be obtained by any suitable known method.
15 For example, the above-described base resin, which is
generally in the form of pellets, and, if desired, one or
more additives are charged, mixed and kneaded in an
extruder. The kneaded mass is then extruded through a die
into strands and cut to obtain the resin particles. It is
20 preferred that the strands be quenched immediately after
being extruded for reasons that the succeeding surface
modification with an organic peroxide, which will be
described hereinafter, may be efficiently performed. The
quenching may be carried out by introducing the strands in
25 water at 50°C or less, preferably 40°C or less, more
preferably 30°C or less. The cooled strands are taken out
of the water and cut into particles each having a
length/diameter ratio of 0.5-2.0, preferably 0.8-1.3, and
a mean weight of 0.1-20 mg, preferably 0.2-10 mg. The
30 mean weight is an average of 200 arbitrarily selected
particles.

The resin particles are dispersed in a dispersing
medium containing an organic peroxide to obtain a
dispersion. Any dispersing medium may be used as long as
35 it can disperse the resin particles therein without

10

substantially dissolving components of the particles.
Examples of the dispersing medium include water, ethylene
glycol, glycerin, methanol, ethanol or a mixture of them.
An aqueous dispersion medium, preferably water, more
5   preferably ion-exchanged water, is suitably used.

The dispersion is heated at a temperature lower than
the melting point of the base resin but sufficient to
decompose the organic peroxide, thereby obtaining
substantially non-crosslinked, surface-modified resin
10   particles. The non-crosslinked, surface-modified resin
particles are then expanded using a blowing agent to
obtain expanded PP beads.
The expanded PP beads have excellent fuse-bonding
properties and give a high rigidity PP molding in a mold
15   using steam at a relatively low temperature.

Any organic peroxide may be used for the purpose of
the present invention as long as it decomposes when heated
at a temperature lower than the melting point of the base
resin.

20   Illustrative of suitable organic peroxides are shown
below together with 1 Hr half life temperature Th and 1
min half life temperature Tn thereof, which are indicated
in the brackets on the left and right sides, respectively,
of the slash (/) and which will be discussed hereinafter:
25   Isobutylperoxide [50°C/85°C],
Cumyl peroxy neodecanoate [55°C/94°C],
α,α'-Bis(neodecanoylperoxy)diisopropylbenzene [54°C/82°C],
di-n-Propyl peroxydicarbonate [58°C/94°C],
Diisopropyl peroxydicarbonate [56°C/88°C],
30   1-Cyclohexyl-1-methylethyl peroxy neodecanoate [59°C/94°C],
1,1,3,3-Tetramethylbutyl peroxy neodecanoate [58°C/92°C],
Bis(4-t-butylcyclohexyl) peroxydicarbonate [58°C/92°C],
Di-2-ethoxyethyl peroxydicarbonate [59°C/92°C],
Di(2-ethylhexylperoxy)dicarbonate [59°C/91°C],
35   t-Hexyl peroxy neodecanoate [63°C/101°C],

11

Dimethoxybutyl peroxydicarbonate [64°C/102°C],
Di(3-methyl-3-methoxybutylperoxy)dicarbonate [65°C/103°C],
t-Butyl peroxy neodecanoate [65°C/104°C],
2,4-Dichlorobenzoyl peroxide [74°C/119°C],
5   t-Hexyl peroxy pivalate [71°C/109°C],
t-Butyl peroxy pivalate [73°C/110°C],
3,5,5-Trimethylhexanoyl peroxide [77°C/113°C],
Octanoyl peroxide [80°C/117°C],
Lauroyl peroxide [80°C/116°C],
10 Stearoyl peroxide [80°C/117°C],
1,1,3,3-Tetramethylbutyl peroxy 2-ethylhexanoate
[84°C/124°C],
Succinic peroxide [87°C/132°C],
2,5-Dimethyl-2,5-di(2-ethylhexanoylperoxy)hexane
15 [83°C/119°C],
1-Cyclohexyl-1-methylethyl peroxy 2-ethylhexanoate
[90°C/138°C],
t-Hexyl peroxy 2-ethylhexanoate [90°C/133°C],
t-Butyl peroxy 2-ethylhexanoate [92°C/134°C],
20 m-Toluoyl benzoyl peroxide [92°C/131°C],
Benzoyl peroxide [92°C/130°C],
t-Butyl peroxy isobutylate [96°C/136°C],
1,1-Bis(t-butylperoxy)-2-methylcyclohexane [102°C/142°C],
1,1-Bis(t-hexylperoxy)-3,3,5-trimethylcyclohexane
25 [106°C/147°C],
1,1-Bis(t-butylperoxy)-3,3,5-trimethylcyclohexane
[109°C/149°C],
1,1-Bis(t-hexylperoxy)cyclohexane [107°C/149°C],
1,1-Bis(t-butylperoxy)cyclohexane [111°C/154°C],
30 2,2-Bis(4,4-di -butylperoxycyclohexyl)propane
[114°C/154°C],
1,1-Bis(t-butylperoxy)cyclododecane [114°C/153°C],
t-Hexyl peroxy isopropyl monocarbonate [115°C/155°C],
t-Butyl peroxy maleic acid [119°C/168°C],
35 t-Butyl peroxy 3,5,5-trimethylhexanoate [119°C/166°C],

12

t-Butyl peroxy laurate [118°C/159°C],

2,5-Dimethyl-2,5-di(m-toluoylperoxy)hexane [117°C/156°C],

t-Butyl peroxy isopropyl monocarbonate [118°C/159°C],

t-Butyl peroxy 2-ethylhexyl monocarbonate [119°C/161°C],

5   t-Hexyl peroxy benzoate [119°C/160°C], and

2,5-Dimethyl-2,5-di(benzoylperoxy)hexane [119°C/158°C].

These organic peroxides may be used alone or in combination. The amount of the organic peroxide in the dispersion is generally 0.01-10 parts by weight,

10   preferably 0.05-5 parts by weight, more preferably 0.1-3 parts by weight, per 100 parts by weight of the resin particles.

In the dispersion obtained by dispersing the resin particles in a dispersing medium containing an organic

15   peroxide, it is preferred that the weight ratio of the resin particles to the dispersing medium be 1.3:1 or less, more preferably 1.2:1 or less, much more preferably 1.1:1 or less, most preferably 1:1 or less, for reasons of uniformly treating the particles with the organic peroxide.

20   Namely, when the weight ratio of the resin particles to the dispersing medium is excessively high, a difficulty might be caused in uniformly treating the surfaces of the resin particles. Thus, a part of the resin particles which excessively undergo the surface modification tend to

25   for an aggregate in the dispersion so that the discharge of the dispersion from the vessel at the time of the expansion is not smoothly carried out. From the standpoint of economy, the weight ratio of the resin particles to the dispersing medium is desirably at least

30   0.6:1, more preferably at least 0.7:1.

An organic peroxide, when heated, decomposes and generates radicals which causes three types of chain transfer reactions, namely hydrogen extraction, addition and β-degradation. In the case of the present invention,

35   the use of an organic peroxide capable of generating

13

radicals causing addition reactions, especially oxygen
radicals, is preferred. A carbonate-type organic peroxide
is preferred for this reason. The oxygen radicals may be
organic oxy-radical (RO· where R is an organic group
5   derived from the organic peroxide) as well as O-radical
(O·). If desired, a chain transfer agent may be added to
the polypropylene resin particles-containing dispersion or
previously incorporated into the resin particles.
     Hitherto, the following methods are known to use an
10   organic peroxide in connection with a polypropylene resin:
(1) A method in which polypropylene resin particles are
uniformly impregnated with an organic peroxide and a
crosslinking aid, the resulting resin particles being
subsequently heated at a temperature higher than the
15   melting point of the polypropylene resin to decompose the
organic peroxide and to crosslink the polypropylene resin;
(2) A method in which a composition containing
polypropylene and an organic peroxide is kneaded in an
extruder to decompose the organic peroxide and to
20   decompose the polypropylene, thereby obtaining
polypropylene having a narrower molecular weight
distribution (JP-A-H03-152136);
(3) A method in which polypropylene particles are
uniformly impregnated with an organic peroxide and a
25   crosslinking aid, the resulting resin particles being
subsequently heated at a temperature lower than the
melting point of the polypropylene to decompose the
organic peroxide and to introduce a long chain branch or
crosslinking structure into the polypropylene resin. The
30   polypropylene resin particles thus having an improved melt
tension is kneaded with a blowing agent in an extruder and
extruded (JP-A-H11-80262);
(4) A method in which a polypropylene resin is mixed and
kneaded with an organic peroxide and maleic anhydride in
35   an extruder at a temperature higher than the melting point

14

of the polypropylene resin to graft polymerize the maleic
anhydride on the polypropylene resin.

    The method of the present invention in which a
dispersion containing the resin particles and an organic
5   peroxide is maintained at a temperature lower than the
melting point of the base resin but sufficient to
decompose the organic peroxide, thereby obtaining
substantially non-crosslinked, surface-modified resin
particles is thus distinct from the above known methods
10 (1)-(4).

    In the present invention, the organic peroxide is
heated at a temperature lower than the melting point of
the base resin but sufficient to substantially decompose
the organic peroxide. It is preferred that 1 Hr half life
15 temperature Th (the temperature at which the amount of
the organic peroxide decreases to half when the peroxide
is heated at that temperature for 1 hour) of the organic
peroxide be not higher than the Vicat softening point of
the base resin. The "Vicat softening point" in the present
20 specification is in accordance with Japanese Industrial
Standard JIS K 6747-1981. When the 1 Hr half life
temperature Th is higher than the Vicat softening point of
the polypropylene resin, it is difficult to substantially
decompose the organic peroxide at a temperature lower than
25 the melting point of the base resin. When the
decomposition of the organic peroxide is carried out at a
temperature not lower than the melting point of the base
resin, the decomposed organic peroxide will attack not
only the surfaces of the resin particles but also inside
30 regions thereof, so that expanded PP beads obtained cannot
give a desired PP molding.

    Thus, it is preferred that the 1 Hr half life
temperature Th be lower by at least 20°C, more preferably
by at least 30°C, than the Vicat softening point of the
35 base resin. It is also preferred that the 1 Hr half life

15

temperature Th be in the range of 40-100°C, more
preferably 50-90°C, for reasons of easiness of handling.

The organic peroxide in the dispersion is desirably
substantially decomposed at a temperature not higher than,
5   more preferably lower by at least 20°C than, most
preferably lower by at least 30°C than, the Vicat
softening point of the base resin. Further, the organic
peroxide in the dispersion is desirably substantially
decomposed at a temperature not lower than the glass
10 transition point of the base resin, more preferably at a
temperature in the range of 40-100°C, most preferably 50-
90°C, for reasons of easiness in handling of the peroxide.

It is further preferred that the decomposition of
the organic peroxide be performed by maintaining the
15 organic peroxide at a temperature in the range of (Tn −
30°C) to (Tn + 30°C) for at least 10 minutes, where Tn is
1 min half life temperature of the organic peroxide (the
temperature at which the amount of the organic peroxide
decreases to half when the peroxide is heated at that
20 temperature for 1 minute) for reasons of decomposition
efficiency. When the decomposition is carried out at a
temperature lower than (Tn − 30°C), a long time is
required for completing the decomposition. Too high a
decomposition temperature in excess of (Tn + 30°C) might
25 adversely affect the uniformity of surface treatment.
From the standpoint of process cost and efficiency, the
heat treatment at a temperature of (Tn − 30°C) to (Tn +
30°C) is desired to be performed for 60 minutes or shorter.
Preferably, the dispersion of the resin particles in the
30 organic peroxide-containing liquid medium is prepared at
such a temperature that the peroxide is prevented from
decomposing and, then, the temperature is increased
continuously or stepwise so that the peroxide is
maintained at a temperature range of (Tn − 30°C) to (Tn +
35 30°C) for at least 10 minutes. In this case, it is

16

preferred that the peroxide be maintained at a constant temperature of (Tn − 5°C) to (Tn + 5°C) for at least 5 minutes.

The term "substantially decompose" as used herein
5   means that the active oxygen content of the peroxide is reduced to less than 50 % of the original value. Preferably, the peroxide is decomposed so that the active oxygen content thereof be reduced to 30 % or less, more preferably 20 % or less, most preferably 5 % or less of
10 the original value.

The "1 hour half life temperature Th" and "1 min half life temperature Tn" of the organic peroxide are measured as follows. A sample peroxide is dissolved in a suitable solvent inert to radicals, such as benzene or
15 mineral spirit, to obtain a solution having a peroxide concentration of 0.1 mol/L or 0.05 mol/L. This is placed in a glass tube whose inside space has been substituted by nitrogen. The glass tube is sealed and immersed in a constant temperature bath maintained at a predetermined
20 temperature for a given period (1 minute or 1 hour) to permit the peroxide to decompose. The change in concentration of the organic peroxide with the time is measured. Under the above reaction conditions, since the decomposition reaction of the organic peroxide can be
25 regarded as being a first-order reaction, the following equations can be formed:

$$dx/dt = k(a - x)$$

$$\ln[a/(a - x)] = kt$$

wherein x denotes a concentration of the organic peroxide,
30 a denotes the initial concentration of the organic peroxide, k denotes the decomposition rate constant, and t denotes a time. Since the half-life period $t_{1/2}$ is a time required for reducing the concentration of the organic peroxide to half by decomposition (x = a/2), the following
35 relationship is obtained:

17

$$kt_{1/2} = \ln 2.$$

From the above measurement of the change in concentration
of the organic peroxide with the time (t), relationship
between the time (t) and $\ln[a/(a-x)]$ is plotted to give a

5   straight line. The gradient represents the constant (k).
Thus, the half life $t_{1/2}$ is calculated from the above
equation. The 1 Hr half life temperature and 1 min half
life temperature of an organic peroxide are the
temperatures at which $t_{1/2}$ of the organic peroxide are 1

10   hour and 1 minute, respectively.

The "glass transition point" as used herein is
measured in accordance with JIS K7121-1987 and is
calculated from the midpoint of a heat flux. The "glass
transition point is measured after the sample has been

15   heat treated under specified conditions".

In the present invention, the polypropylene resin,
the base resin, the resin particles, the surface-modified
resin particles, expanded PP beads and PP molding are
substantially non-crosslinked. The term "substantially

20   non-crosslinked" as used herein is as defined below.
Sample resin is immersed in xylene (100 ml xylene per 1 g
sample resin) and the mixture is refluxed for 8 hours. The
mixture is then immediately filtered through a 74 µm wire
net (specified in Japanese Industrial Standard JIS Z8801 –

25   1966-). The dry weight of the xylene-insoluble matters
left on the wire net is measured. A crosslinking degree P
(%) is calculated from the formula:

$$P\ (\%) = (M/L) \times 100$$

wherein M represents the weight (g) of the xylene-

30   insoluble matters and L represents the weight (g) of the
sample. "Substantially non-crosslinked" means that the
crosslinking degree P is 10 % or less.

In the present invention, the crosslinking degree P
of the base resin, the resin particles, the surface-

35   treated (or surface modified) resin particles, expanded PP

18

beads and PP molding is preferably 5 % or less, more
preferably 3 % or less, most preferably 1 % or less. In
general, the surface treatment does not result in an
increase of the crosslinking degree P.

5   The surface-modified resin particles are then foamed
and expanded to obtain expanded PP beads using a blowing
agent. Preferably, the expansion step is carried out by a
conventional dispersion method in which the resin
particles are dispersed in a dispersing medium in a closed

10   vessel in the presence of a blowing agent and heated to
impregnate the resin particles with the blowing agent.
While being maintained under a pressurized condition and
at a temperature sufficient to expand the resin particles,
the dispersion is discharged from the vessel to an

15   atmosphere of a pressure lower than the pressure in the
vessel, thereby obtaining expanded PP beads.

          While the surface modification of the resin
particles with the organic peroxide and the subsequent
expansion of the surface-modified resin particles may be

20   carried out in separate vessels, it is preferred that that
the expansion step be carried out by the dispersion method
and that the expansion step be carried out in the same
vessel for reasons of efficiency. Namely, the surface
modification the resin particles and expansion of the

25   surface-modified resin particles may be carried out by
simply conducting the dispersion method after addition of
a predetermined amount of the organic peroxide in the
dispersion.

          In performing the expansion, it is preferred that

30   the weight ratio of the surface-modified resin particles
to the dispersing medium be 0.5:1 or less, preferably
0.1:1 to 0.5:1, for reasons of prevention of melt adhesion
of the surface-modified resin particles in the dispersion.
Thus, when the surface modification of the resin particles

35   is carried out in a vessel with the ratio of the resin

19

particles to the dispersing medium being maintained in a
range of 0.6:1 to 1.3:1, and when the expansion is
performed in the same vessel, a fresh dispersing medium is
added to the vessel before subjecting the dispersion to
5   the expansion step.

The surface-modified resin particles, expanded PP
beads obtained therefrom and PP molding obtained from the
beads may contain 100-8000 ppm by weight of an alcohol
having a molecular weight of 50 or more and produced by
10   the decomposition of the organic peroxide. For example,
p-t-butylcyclohexanol may be present in the expanded PP
beads, when bis(4-t-butylcyclohexyl)peroxydicarbonate is
used as the organic peroxide. i-Propanol, s-butanol, 3-
methoxybutanol, 2-ethylhexylbutanol or t-butanol may be
15   detected, when the corresponding peroxide is used.

To prevent melt-adhesion of the surface-treated
resin particles with each other during the expansion step,
it is desirable to add to the dispersing medium a
dispersing agent which is finely divided organic or
20   inorganic solids. For reasons of easiness of handling, the
use of an inorganic powder is preferred. Illustrative of
suitable dispersing agents are natural or synthetic clay
minerals (such as kaolin, mica, pyrope and clay), alumina,
titania, basic magnesium carbonate, basic zinc carbonate,
25   calcium carbonate and iron oxide. The dispersing agent is
generally used in an amount of 0.001-5 parts by weight per
100 parts by weight of the resin particles.

To improve the dispersing efficiency of the
dispersing agent, namely to reduce the amount of the
30   dispersing agent while retaining its function to prevent
melt-adhesion of the surface-treated particles, a
dispersion enhancing agent may be preferably added to the
dispersing medium. The dispersion enhancing agent is an
inorganic compound capable of being dissolved in water in
35   an amount of at least 1 mg in 100 ml of water at 40°C and

20

of providing divalent or trivalent anion or cation.
Examples of the dispersion enhancing agents include
magnesium chloride, magnesium nitrate, magnesium sulfate,
aluminum chloride, aluminum nitrate, aluminum sulfate,

5   ferric chloride, ferric sulfate and ferric nitrate. The
dispersion enhancing agent is generally used in an amount
of 0.0001-1 part by weight per 100 parts by weight of the
polypropylene resin particles.

        The blowing agent may be an organic physical blowing

10   agent or an inorganic physical blowing agent. Examples of
the organic physical blowing agents include aliphatic
hydrocarbons such as propane, butane, pentane, hexane and
heptane, alicyclic hydrocarbons such as cyclobutane and
cyclohexane, and halogenated hydrocarbons such as

15   chlorofluoromethane, trifluoromethane, 1,2-difluoroethane,
1,2,2,2-tetrafluoroethane, methylchloride, ethylchloride
and methylenechloride. Examples of inorganic physical
blowing agents include air, nitrogen, carbon dioxide,
oxygen, argon and water. These organic and inorganic

20   blowing agents may be used singly or as a mixture of two
or more. For reasons of stability (uniformity) of
apparent density of expanded PP beads, low costs and
freedom of environmental problem, the use of air or
nitrogen is preferred. Water as the blowing agent may be

25   that used in dispersing the surface-modified resin
particles in the dispersing medium.

        The amount of the blowing agent may be suitably
determined according to the kind of the blowing agent,
expansion temperature and apparent density of the expanded

30   PP beads to be produced. When nitrogen is used as the
blowing agent and when water is used as the dispersing
medium, for example, the amount of nitrogen is preferably
such that the pressure within the closed vessel in a
stable state immediately before the initiation of the

35   expansion, namely the pressure (gauge pressure) in the

upper space in the closed vessel, is in the range of 0.6-8
MPa(G). In general, the pressure in the upper space in
the closed vessel is desirably increased as the apparent
density of the expanded PP beads to be obtained is reduced.

5   It is preferred that the expansion of the surface-
modified resin particles be performed so that the expanded
PP beads have an apparent density of 10 g/L to 500 g/L.
The apparent density (g/L) is obtained by dividing the
weight W (g) of the expanded PP beads by the volume V (L)

10   of the apparent volume thereof (density = W/V). The
apparent volume is measured as follows:

        In a measuring cylinder, about 5 g of expanded PP
beads are allowed to stand at 23°C for 48 hours in the
atmosphere and thereafter immersed in 100 ml water

15   contained in a graduation cylinder at 23°C. From the
increment of the volume, the apparent volume can be
determined.

        It is preferred that the expansion of the surface-
modified resin particles be performed so that the expanded

20   PP beads have a high temperature endothermic peak, in a
DSC curve thereof, in addition to an intrinsic endothermic
peak located at a lower temperature side of the high
temperature peak, because the expanded PP beads have high
content of closed cells and extremely suited to obtain a

25   high rigidity PP molding.

        The high temperature peak preferably has such an
area corresponding to heat of fusion (calorific value;
absolute value) in the range of 2-70 J/g, more preferably
3-65 J/g, most preferably 12-58 J/g. When the heat of

30   fusion of the high temperature peak is less than 2 J/g,
the compression strength and shock absorbing power of a PP
molding tend to be reduced. Too high a heat of fusion of
the high temperature peak in excess of 70 J/g requires a
high pressure to increase the inside pressure in the beads

35   before the molding step. It is preferred that the heat of

22

fusion of the high temperature peak is 10-60 %, more
preferably 20-50 %, of a total of the heat of fusion of
the high temperature peak and the heat of fusion of the
intrinsic peak. The total heat of fusion is suitably in
5   the range of 40-150 J/g.

The DSC curve herein is as obtained by the
differential scanning calorimetric analysis wherein a
sample (2-4 mg of expanded PP beads) is heated from room
temperature (10-40°C) to 220°C in an atmosphere of
10 nitrogen at a rate of 10°C/min. FIG. 1 shows an example
of a DSC curve having an intrinsic endothermic peak P1 at
a peak temperature T1 and a high temperature endothermic
peak P2 at a peak temperature T2. The area of a peak
corresponds to the heat of fusion thereof.
15 The area of the high temperature peak P2 is
determined as follows. In the DSC curve (first DSC curve)
C having two endothermic peaks P1 and P2 at temperatures
T1 and T2, respectively, as shown in Fig. 1, a straight
line A extending between the point Z1 in the curve at 80°C
20 and the point Z2 in the curve at a melt completion
temperature Tmc is drawn. The melt completion temperature
Tmc is represented by a point at which the high
temperature peak P2 ends and meets the base line on a high
temperature side. Next, a line B which is parallel with
25 the ordinate and which passes a point B_c between the peaks
P1 and P2 is drawn. The line B crosses the line A at a
point B_A. The position of the point B_c is such that the
length between the point B_A and the point B_c is minimum.
The area of the high temperature peak P2 is the shaded
30 area defined by the line A, line B and the DSC curve C.
A total of the heat of fusion of the high temperature peak
P2 and the heat of fusion of the intrinsic peak P1
corresponds to an area defined by the line A and the DSC
curve.
35 When expanded PP beads having a weight per bead of

23

less than 2 mg are measured for the intrinsic peak P1 and
high temperature peak P2 using a differential scanning
calorimeter, two or more beads are sampled for the
measurement such that the total weight of the sample is in
5   the range of 2-10 mg. When expanded PP beads to be
measured have a weight per bead of 2-10 mg, one bead is
sampled for the DSC measurement. When expanded PP beads
to be measured have a weight per bead of more than 10 mg,
one of the beads is cut into two or more pieces and one of
10   the pieces having a weight of 2-10 mg is sampled for the
DSC measurement. In this case, an expanded PP bead having
a weight W and an outer peripheral surface area of S is
preferably cut into n number of pieces so that cut pieces
have nearly equal weight of W/n and have a surface portion
15   which is derived from the outer peripheral surface of the
bead and which has an area of nearly S/n. For example,
when the expanded PP beads to be measured have a weight
per bead of 18 mg, one of the beads is cut along a plane
bisecting the bead and one of the cut pieces is used for
20   measurement. In the present specification, except
otherwise noted, the term "heat of fusion of the high
temperature peak of expanded PP bead(s)" is intended to
refer to the heat of fusion as measured in the above-
described method, and should be discriminated from "heat
25   of fusion of the high temperature peak of a surface region
or an inside region of an expanded PP bead" which will be
described hereinafter.

The above-described high temperature peak P2 is
present in the DSC curve measured first. Once the
30   expanded PP beads have completely melted, the high
temperature peak P2 no longer appears. Thus, when the
sample after the first DSC measurement is cooled to room
temperature (10-40°C) and is measured again for a DSC
curve by heating to 220°C in an atmosphere of nitrogen at
35   a rate of 10°C/min, the second DSC curve does not show

24

such a high temperature peak but contains an endothermic
peak attributed to the melting of the base resin, just
like a DSC curve shown in FIG. 2.

In the present specification and claims, the term
5   "melting point of the base resin" is intended to refer to
that measured by DSC analysis of base resin particles
which have not yet been subjected to surface modification
treatment with an organic peroxide. Namely, "melting point
of the base resin" is measured by the differential
10 scanning calorimetric analysis wherein a sample (2-4 mg of
resin particles of the base resin) is heated from room
temperature (10-40°C) to 220°C in an atmosphere of
nitrogen at a rate of 10°C/min. The sample is then cooled
to room temperature (10-40°C) and is measured again for a
15 DSC curve by heating to 220°C in an atmosphere of nitrogen
at a rate of 10°C/min to obtain a second DSC curve as
shown in FIG. 2. The temperature Tm of the endothermic
peak P3 at 130-170°C in the second DSC curve as shown in
Fig. 2 is inherent to the polypropylene resin and
20 represents the "melting point of the base resin". Two or
more endothermic peaks might be observed in the second DSC
curve, when, for example, the resin particles are composed
of two or more different polypropylene resins. In this
case, the melting point Tm is the peak temperature of that
25 peak which has the greatest peak height among those peaks.
When there are a plurality of peaks having the same
greatest peak height, then the melting point Tm is the
highest peak temperature among those peaks. The term
"peak height" herein refers to the length S between the
30 top of the peak P3 and a point Q at which a line parallel
with the ordinate and passing through the top of the peak
P3 crosses the base line B_L. In Fig. 2, the temperature Te
at which the endothermic peak P3 ends and meets the base
line B_L refers to the "melt completion temperature of the
35 base resin".

25

The high temperature peak P2 of expanded PP beads
generally appears at a temperature T2 ranging from (Tm +
5°C) to (Tm + 15°C). The endothermic peak P1 of expanded
PP beads generally appears at a temperature T1 ranging

5   from (Tm - 5°C) to (Tm + 5°C). The endothermic peak in the
second DSC measurement of expanded PP beads generally
corresponds to that in the second DSC curve of the
precursor base resin particles and generally appears at a
temperature ranging from (Tm - 2°C) to (Tm + 2°C).

10   As described above, it is preferred that the
expanded PP beads have such a crystal structure that a
high temperature peak is present in a first DSC curve
thereof in addition to an intrinsic peak. A difference
between the melting point of the polypropylene resin and

15   expansion temperature has a great influence upon the heat
of fusion (peak area) of the high temperature peak.

The heat of fusion of the high temperature peak of
the expanded PP beads is a factor for determining the
minimum temperature of steam which provides a saturated

20   steam pressure required for melt-bonding the beads to each
other. In general, when the same base resin is used, the
smaller the heat of fusion of the high temperature peak,
the lower becomes the minimum temperature. Further, the
higher the expansion temperature, the smaller becomes the

25   heat of fusion of the high temperature peak.

When expanded PP beads having a small heat of fusion
of the high temperature peak are used, the mechanical
properties of the resulting PP molding are relatively low,
though the minimum temperature required for melt-bonding

30   the beads can be low. On the other hand, when expanded PP
beads having a large heat of fusion of the high
temperature peak are used, the mechanical properties of
the resulting PP molding are relatively high. In this
case, however, since the minimum temperature required for

35   melt-bonding the beads is high, it is necessary to use

26

high pressure steam for the production of PP moldings.
Thus, the most preferred expanded PP beads would be such
that the heat of fusion of the high temperature peak
thereof is large but the minimum temperature required for
5   melt-bonding the beads is low. The present invention does
provide such ideal expanded PP beads. The expanded PP
beads according to the present invention can give a high
rigidity PP molding without using a high temperature steam.
     The expanded PP beads providing a DSC curve having
10   such a high temperature peak can be suitably produced by
maintaining the dispersion containing the surface-modified
resin particles in a vessel at a first fixed temperature
between a temperature lower by 20°C than the melting point
of the base resin (Tm - 20°C) and a temperature lower than
15   the melt completion point of the base resin (Te) for a
period of time of preferably 10 - 60 min, preferably 15 -
60 min and then discharging the dispersion from the vessel
after increasing the temperature of the dispersion to a
second fixed temperature between a temperature lower by
20   15°C than the melting point of the base resin (Tm - 15°C)
and a temperature higher by 10°C than the melt completion
point of the base resin (Te + 10°C) or, if necessary,
after maintaining the dispersion at the second fixed
temperature for a period of time of 10 - 60 min.
25   The area of the high temperature peak mainly depends
upon the above first fixed temperature at which the
dispersion is maintained before expansion treatment, the
time for which the dispersion is maintained at the first
fixed temperature, the above second fixed temperature, the
30   time for which the dispersion is maintained at the second
fixed temperature, the heating rate at which the
dispersion is heated to the first fixed temperature and
the heating rate at which the dispersion is heated from
the first fixed temperature to the second fixed
35   temperature. The area of the high temperature peak

27

increases with an increase of the retention time at the
first and second fixed temperatures. The heating rate
(average heating rate from the commencement of heating
until the fixed temperature is reached) in each of the
5   heating stage up to the first fixed temperature and the
succeeding heating stage from the first fixed temperature
to the second fixed temperature is generally 0.5-5°C per
minute. Suitable conditions for the preparation of
expanded PP beads having desired heat of fusion of the
10   high temperature peak can be determined by preliminary
experiments on the basis of the above points.

The above temperature ranges for the formation of
the high temperature peak and for the expansion of the
resin particles are suitably adopted in the case where an
15   inorganic physical blowing agent is used. When an organic
physical blowing agent is used, the suitable temperature
ranges will shift toward low temperature side and vary
with the kind and amount of the organic physical blowing
agent.

20   The expanded PP beads used for the production of a
foamed molding according to the present invention
preferably have at least one of the following
characteristics.

A surface region of the expanded PP bead preferably
25   has a melting point (Tms) lower than the melting point
(Tmi) of an inside region thereof ($Tms < Tmi$). The
difference between the melting point ($Tmi - Tms$) is
preferably at least 0.05°C, more preferably at least 0.1°C,
most preferably at least 0.3°C. The melting point Tms is
30   determined as follows. A surface region of the expanded
PP bead is cut and about 2-4 mg of such cut samples are
collected. The sample is subjected to DSC analysis in the
same manner as described previously with regard to the
measurement of the melting point Tm. The peak temperature
35   of a peak corresponding to the endothermic peak P3 in the

28

second DSC curve represents the melting point Tms. The
melting point Tmi is also measured in the same manner as
above except that inside region of the bead is cut and
collected.

5   In the case of the expanded PP bead having a high
temperature endothermic peak in a DSC curve thereof, the
heat of fusion Hs of the high temperature endothermic peak
of the surface region of the bead is preferably smaller
than the heat of fusion Hi of the high temperature
10   endothermic peak of the inside region of the bead such
that the following relationship is established:
              Hs < 0.86×Hi
for reasons that the expanded PP beads can be molded at a
lower temperature as compared with surface unmodified
15   expanded PP beads. Such an effect increases with a
decrease of Hs. Thus, the Hs and Hi of the expanded PP
bead preferably have the following relationship: Hs <
0.83×Hi, more preferably Hs < 0.80×Hi,
              still more preferably Hs < 0.75×Hi,
20   yet still more preferably Hs < 0.70×Hi,
              most preferably Hs < 0.60×Hi.
Preferably, Hs is not smaller than 0.25×Hi (Hs ≥ 0.25×Hi)..
        . It is also preferred that Hs is in the range of 1.7-
60 J/g, more preferably 2-50 J/g, still more preferably 3-
25   45 J/g, most preferably 4-40 J/g, for reasons of
availability of a low molding temperature

        The surface region and inside region of an expanded
PP bead are sampled by cutting the bead with a knife or a
microtome. The surface region or regions are sliced off
30   the bead at any arbitral position or positions to a
thickness of 200 μm or less such that the outer surface of
the bead provides one of the both sides of each of the
sliced surface regions. Thus, the other side of each of
the sliced surface regions does not contain that part of
35   the PP bead which was present at a depth of more than 200

29

µm before cutting. The depth herein is in the direction
from the outer surface of the bead to the center of
gravity thereof. When the sliced surface region or
regions contain that part of the PP bead which was present
5   at a depth of more than 200 µm, precise data cannot be
obtained. When the amount of the surface region or
regions sampled from the bead is less than 2 mg, one or
more additional beads are cut to collect 2-4 mg of the
sample.
10   The inside region is obtained by removing all of the
surface region of the bead up to the depth of 200 µm in
the direction from the outer surface of the bead to the
center of gravity thereof. When the size of the bead is
so small that no inside region is obtainable after removal
15   of surface region of the 200 µm thick, then the inside
region is obtained by removing all of the surface region
of the bead up to the depth of 100 µm in the direction
from the outer surface of the bead to the center of
gravity thereof. When the size of the bead is so small
20   that no inside region is obtainable after removal of
surface region of the 100 µm thick, then the inside region
is obtained by removing all of the surface region of the
bead up to the depth of 50 µm in the direction from the
outer surface of the bead to the center of gravity thereof.
25   When the amount of the inside region obtained from one
bead is less than 2 mg, one or more additional beads are
used to collect 2-4 mg of the sample. The thus collected
samples are measured for the melting point and heat of
fusion of the high temperature peak according to the
30   method described above.
       The expanded PP bead preferably has a surface having
a melt initiation temperature, as measured by micro
differential thermoanalysis, not higher than the melting
point of the base resin. In the conventional expanded PP
35   beads, the melt initiation temperature is higher by at

30

least 5°C than the melting point of the base resin.

Further, the expanded PP bead preferably has a
surface having an extrapolated melt initiation temperature,
as measured by micro differential thermoanalysis, not
5   higher than (Tm + 4°C) where Tm is the melting point of
the base resin. In the conventional expanded PP beads,
the extrapolated melt initiation temperature is higher by
at least 8°C than the melting point (Tm).

The micro differential thermoanalysis (µDTA) is
10   performed using a micro differential thermoanalysis system
("Type 2990 Micro Thermal Analyzer" of T. A. Instrument,
Japan Inc.) at a heating rate of 10°C/sec from 25°C to
200°C. The "melt initiation temperature" as used herein
is intended to refer to a temperature at which a µDTA
15   curve starts separating from the base line thereof. The
"extrapolated melt initiation temperature" as used herein
is intended to refer to a temperature at the intersection
of the base line and a tangential line drawn from such a
point on the µDTA curve on the higher temperature side of
20   the melt initiation temperature that the gradient of the
tangential line relative to the base line is maximum. For
example, in the lower µDTA curve Cm shown in FIG. 3, Pm
and Pme represent the melt initiation temperature (about
131°C) and extrapolated melt initiation temperature (about
25   135°C), respectively. At Pme, a tangentially extrapolated
line TL extending from a point Km on the curve Cm
intersects the base line BL. The point Km is so located
on the higher temperature side of the melt initiation
temperature Pm as to provide the maximum gradient of the
30   tangential line TL relative to the base line BL.
Similarly, in the upper µDTA curve Cnm, Pnm and Pnme
represent the melt initiation temperature (about 168°C)
and extrapolated melt initiation temperature (about 171°C),
respectively. In FIG. 5, Pm and Pme represent the melt
35   initiation temperature (about 140°C) and extrapolated melt

31

initiation temperature (about 142°C), respectively.

The µDTA is performed by fixing a sample expanded PP
bead on a sample stage. When the bead has an excessively
5   large size, the bead may be cut into a suitable size. A
probe tip of the thermal analyzer is directed toward an
arbitral region of the surface of the bead and then
displaced to contact with the surface of the bead. Then,
the measurement is carried out while maintaining the
10   contact state. The probe tip has a size of 0.2 µm × 0.2
µm. Similar measurement is repeated at 10 different
positions on a surface of the bead to obtain 10 µDTA
curves in total, from each of which the melt initiation
temperature and extrapolated melt initiation temperature
15   are determined. The "melt initiation temperature" and
"extrapolated melt initiation temperature" as used herein
are each an arithmetic mean of the eight values remaining
after omitting the maximum and minimum values from the ten
measured values. When two or more maximum and/or two or
20   more minimum values exist, an arithmetic mean is
calculated from the values remaining after omitting the
maximum and minimum values. When all of the ten measured
values are the same, then that value represents the
arithmetic mean. When there are no other values than the
25   maximum and minimum values and when the difference between
them is not greater than 10°C, then an arithmetic mean of
the ten values is adopted. When there are no other values
than the maximum and minimum values and when the
difference between them is greater than 10°C, then µDTA is
30   repeated for another ten different points until the above-
defined "melt initiation temperature" and "extrapolated
melt initiation temperature" are determined.
The reduction of the melt initiation temperature
and/or melt initiation temperature in the expanded PP
35   bead of the present invention is considered to contribute

32

to a reduction of the minimum temperature required for
melt-bonding the beads. The melt initiation temperature
is preferably Tm or less, more preferably (Tm - 5°C) or
less, even more preferably (Tm - 10°C) or less, still more

5   preferably (Tm - 15°C) or less, yet still more preferably
(Tm - 50°C) to (Tm - 16°C), most preferably (Tm - 35°C) to
(Tm - 17°C). The extrapolated melt initiation temperature
is preferably (Tm - 1°C) or less, more preferably (Tm -
6°C) or less, even more preferably (Tm - 11°C) or less,

10   still more preferably (Tm - 16°C) or less, most
preferably (Tm - 35°C) to (Tm - 17°C).
         Such a reduction of the minimum temperature required
for melt-bonding the beads is particularly advantageous
when the base resin of the expanded PP beads has a melting

15   point of 158°C or more and when the expanded PP beads has
a high temperature peak. When the base resin of the
expanded PP beads has a melting point of 158°C or more, it
is preferred that the melt initiation temperature be 158°C
or less, more preferably 155°C or less, still more

20   preferably 150°C or less, yet still more preferably 110-
147°C , most preferably 125-145°C.
While the lower the melt initiation temperature of the
surfaces of the expanded PP beads is, the lower is the
minimum temperature required for melt-bonding the beads,

25   an excessively low melt initiation temperature will cause
a reduction of mechanical strength, such as compression
strength, of a PP molding obtained from the expanded PP
beads.
         The expanded PP bead preferably has an MFR value

30   which is not smaller than that of the resin particles
before the surface modification with the organic peroxide
and which is in the range of 0.5-150 g/10 min, more
preferably 1-100 g/10 min, most preferably 10-80 g/10 min.
It is also preferred that the MFR value of the expanded

35   PP bead be at least 1.2 times, more preferably at least

1.5 times, most preferably 1.8-3.5 times, that of the
resin particles prior to the surface modification.

For measuring the MFR, the expanded PP beads are
pressed at 200°C using a heat press into a sheet having a
5   thickness of 0.1-1 mm. Pellets or columns are prepared
from the sheet to obtain a sample. The sample is measured
for MFR in accordance with the Japanese Industrial
Standard JIS K7210-1976, Test Condition 14. In the
measurement of MFR, air bubbles must be removed from the
10   sample. If necessary, heat press treatment should be
repeated up to three times in total to obtain bubble-free
sheet.

The expanded PP bead preferably has a surface region
having a greater oxygen content per unit weight than that
15   of the inside region. When the organic peroxide used for
the surface modification of the resin particles is of a
type which generates oxygen radicals upon being decomposed,
part of the oxygen radicals are bound to surfaces of the
particles. The analysis, using an infrared spectrometer
20   equipped with the attenuated total reflectance (ATR
analysis), of a surface of a PP molding obtained from
expanded PP beads of the present invention shows a
stronger absorption at a wavelength of near 1033 cm^{-1} than
that of a PP molding obtained from conventional expanded
25   PP beads. Thus, the ratio of the peak height at 1033 cm^{-1}
to the peak height at 1166 cm^{-1} in the case of the PP
molding of the present invention is greater than that of
the conventional molding. Further, the analysis using an
energy dispersion spectroscope (EDS) shows that a surface
30   of the expanded PP bead according to the present invention
has an oxygen to carbon molar ratio (O/C molar ratio) is
0.2 whereas an inside of the bead has an O/C molar ratio
of 0.1. Further, a surface of the conventional expanded
PP bead has O/C molar ratio of 0.1. The preferred O/C
35   ratio is at least 0.15.

34

Although not wishing to be bound by the theory, such an oxygen-added surface of the expanded PP bead is considered to enhance steam permeability thereof. As a result of one of the foregoing characteristics (namely,

5    $Tms < Tmi$; $Hs < 0.86 \times Hi$; melt initiation temperature $\leq$ melting point; extrapolated melt initiation temperature $\leq$ melting point + 4°C; and oxygen-added surface) or as a result of synergetic effect of two or more of the foregoing characteristics, the minimum temperature

10   required for melt-bonding the beads is lowered while ensuring high mechanical strengths of a PP molding obtained from the beads.

The expanded PP beads obtained by the above process are aged in the atmosphere. If desired, the PP beads may

15   be treated to increase the pressure inside of the cells thereof and, thereafter, heated with steam or hot air to improve the expansion ratio thereof.

A PP molding may be suitably obtained by a batch-type molding method in which expanded PP beads (if

20   necessary, after being treated to increase the pressure inside of the cells thereof) are filled in a mold adapted to be heated and cooled and to be opened and closed. After closing the mold, saturated steam is fed to the mold to heat and fuse-bond the beads together. The mold is

25   then cooled and opened to take a PP molding out of the mold. A number of molding machines are commercially available. They are generally designed to have a pressure resistance of 0.41 MPa(G) or 0.45 MPa(G). Thus, the above method is generally carried out using steam having a

30   pressure of 0.45 MPa(G) or less, more preferably 0.41 MPa(G) or less.

A PP molding may be also produced by a continuous method in which expanded PP beads (if necessary, after being treated to increase the pressure inside of the cells

35   thereof) are fed to a path which is defined between a pair

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of belts continuously running in the same direction and
which has a heating zone and a cooling zone. During the
passage through the heating zone, the expanded PP beads
are heated with saturated steam and fuse-bonded to each
5   other. The resulting molding is cooled in the cooling
zone, discharged from the path and cut to a desired length.
The above continuous method is disclosed in, for example,
JP-A-H09-104026, JP-A-H09-104027 and JP-A-H10-180888.
     The above-mentioned treatment of the expanded PP
10   beads to increase the pressure inside of the cells thereof
may be carried out by allowing the beads to stand for a
suitable period of time in a closed vessel to which a
pressurized gas has been fed. Any gas containing an
inorganic gas as a major ingredient may be used for the
15   pressure increasing treatment as long as it is in the form
of gas under conditions where the expanded beads are
treated. Examples of the inorganic gas include nitrogen,
oxygen, air, carbon dioxide and argon. Nitrogen or air is
suitably used for reasons of costs and freedom of
20   environmental problems.
     Described below will be a specific method of
increasing the inside pressure of the cells using air and
a method of measuring the thus increased inside pressure
in the cells.
25   Expanded PP beads are placed in a closed vessel into
which pressurized air is fed. The beads are allowed to
stand in the vessel for a certain period of time
(generally several hours) while maintaining the pressure
inside the vessel at 0.98-9.8 MPaG so that the inside
30   pressure of the cells increases. The thus treated
expanded PP beads are placed in a mold for the production
of a PP foam molding. The inside pressure of the cells P_i
($MPa(G)$) as used herein is defined as follows:
        $P_i = W_i \times R \times T_e / (M \times V)$
35   wherein

Wi is an amount of air increased (g),

R is the gas constant and is 0.0083 (MPa·L/(K·mol),

Te is an ambient temperature and is 296K,

M is the molecular weight of air and is 28.8 (g/mol), and

5 V is the volume (liter) of the air in the expanded beads.

The amount of air increased Wi (g) is measured as follows.

A quantity of expanded beads whose cells have been just pressurized with air in the vessel are taken out of

10 the vessel and collected in a polyethylene film bag having a size of 70 mm × 100 and provided with a multiplicity of perforations each having a size preventing the passage of the beads. The beads in the bag are placed, within 60 seconds after the take-out, on a weighing device provided

15 in a thermostatic chamber maintained at 23°C and 50 % relative humidity under ambient pressure. The weight Ua (g) of the beads is measured just 120 seconds after the expanded beads have been taken out from the vessel. The expanded beads are then allowed to stand for 48 hours in

20 the chamber at 23°C and 50 % relative humidity under ambient pressure. The air in the cells of the expanded beads gradually permeates through the cell walls and escapes from the beads. Therefore, the weight of the beads decreases with the lapse of time. However, an

25 equilibrium has been established and the weight decrease no longer occurs after lapse of the 48 hours period. Thus, the weight of the expanded beads Ub (g) is measured in the same chamber after the lapse of the 48 hours period. Of course, the weight of the polyethylene bag is also

30 measured and taken in consideration. The measurement of the weight should be carried out precisely to the fourth decimal place (0.0001 g). The balance between the weights Ua and Ub represents the amount of gas increased (Wi = Ua − Ub).

35 The volume of the air in the expanded PP beads V (L)

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is defined as follows.

$$V\ (L)\ =\ Va\ -\ Vb$$

wherein

Va is the apparent volume of the expanded PP beads, and

5   Vb is the volume of the base resin of the beads and is
obtained by dividing the weight of the beads Ub (g) by the
density of the base resin (g/L).

The apparent volume Va (L) of the expanded PP beads
is measured as follows. The expanded PP beads which have

10 been subjected to the measurement of the weight Ub as
described above, are immersed in 100 ml of water at 23°C
contained in a graduated measuring cylinder. From the
volume increment, apparent volume Va (L) of the beads is
determined. The quantity of the above-described expanded

15 beads sampled and collected in the bag is such that Ub and
Va fall within the ranges of 0.5 to 10 g and 50 to 90 cm^3,
respectively.

The inside pressure Pi of the cells of the expanded
PP beads is preferably 0.98 MPa(G) or less, more

20 preferably 0.69 MPa(G) or less, still more preferably 0.69
MPa(G) or less. The apparent density of the PP molding
obtained by the above methods may be controlled as desired
and is generally in the range of 9-600 g/L. The term
"apparent density" of the PP molding as used herein is as

25 specified in JIS K7222-1999. The volume of a PP molding
used for the calculation of the apparent density is
determined from the external dimensions thereof. When the
external shape of the molding is so complicated that the
volume thereof is difficult to be determined, then the

30 volume thereof is measured by immersing the molding in
water and is given as a volume of water replaced by the
molding. The PP molding preferably has open cell content
(according to ASTM-D2856-70, Procedure C) of 40 % or less,
more preferably 30 % or less, most preferably 25 % or less,

35 for reasons of high mechanical strengths.

38

A surface layer, such as a reinforcing layer or a
decorative layer) may be integrally provided on a surface
of the above PP molding. A method of producing such a
composite article is disclosed in, for example, US-A-
5 5928776, US-A-6096417, US-A-6033770, US-A-5474841, EP-B-
477476, WO98/34770, WO98/00287 and JP-B-3092227, the
disclosure of which is hereby incorporated by reference
herein.

An insert may be integrated with the above PP
10 molding such that at least part of the insert is embedded
therein. A method of producing such a composite article
is disclosed in, for example, US-A-6033770, US-A-5474841,
JP-A-S59-1277714 and JP-B-3092227, the disclosure of which
is hereby incorporated by reference herein.

15   The following examples will further illustrate the
present invention. Parts are by weight.

Examples 1-7 and Comparative Examples 1-5
100 Parts of polypropylene resin selected from those
20 shown in Table 1 and indicated in Tables 3-1 and 3-2 were
blended with 0.05 part of zinc borate powder (cell
controlling agent) and the blend was kneaded in an
extruder and extruded into strands. The strands were
immediately introduced in water at 18°C for quenching.
25 The cooled strands were then cut into particles each
having a length/diameter ratio of about 1.0 and a mean
weight of 2 mg.

In a 400 liter autoclave, 100 parts of the above
resin particles are charged together with 220 parts of
30 ion-exchanged water at 18°C, 0.005 part of sodium
dodecylbenzenesulfonate (surfactant), 0.3 part of kaolin
powder (dispersing agent), 0.01 part of aluminum sulfate
powder (dispersion enhancing agent), an organic peroxide
selected from those shown in Table 2 and indicated in
35 Table 3-1 or 3-2 in an amount shown in Table 3-1 or Table

39

3-2, and carbon dioxide (blowing agent) in an amount shown in Table 3-1 or 3-2. The mixture in the autoclave was dispersed with stirring and heated to a temperature lower by 5°C than the expansion temperature shown in Table 3-1

5   or 3-2 at an average heating rate of 3°C/min and then maintained at that temperature for 15 min. Thereafter, the temperature was raised to the expansion temperature at an average heating rate of 3°C/min and maintained at that temperature for 15 min. One end of the autoclave was then

10 opened to discharge the dispersion to the atmosphere to obtain expanded PP beads. The discharge was carried out while feeding carbon dioxide gas such that the pressure within the autoclave was maintained at a pressure equal to the pressure in the autoclave immediately before the

15 commencement of the discharge. The expanded PP beads were washed, centrifuged and allowed to stand in the atmosphere for 48 hours for aging. The beads were then measured for heat of fusion of a high temperature peak thereof and melting point and high temperature peaks of surface and

20 insides region thereof. Also measured were MFR and apparent density of the beads. The results are summarized in Tables 3-1 and 3-2. In Table 2, "1 Hr half life temperature" and "1 Min half life temperature" are as defined previously.

25

Table 1

Resin No.	Kind of Resin	Glass Transition Point (°C)	Vicat Softening Point (°C)	MFR (g/ 10 min)	Melting Point (°C)
1	Propylene homopolymer	-21	148	8	163
2	Ethylene-propylene random copolymer	-28	122	4	136
3	Propylene				

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	homopolymer	-20	147	18	162

Table 2

Organic Peroxide No.	Organic Peroxide	1 Hr Half life Temperature (°C)	1 Min Half life Temperature (°C)
1	Benzoyl peroxide	92	130
2	Bis(4-t-butyl-cyclohexyl) per-oxydicarbonate	58	92

The expanded PP beads were placed in a vessel, to
which pressurized air was fed so that the inside pressure
of the cells of the beads was increased to a pressure
shown in Tables 3-1 and 3-2. The resulting beads were
then molded in the manner shown below using a molding
device shown in FIG. 4 to obtain a foamed PP molding
having the properties shown in Tables 3-1 and 3-2.

The molding device had a male mold 1 and a female
mold 2 adapted to be displaced relative to each other.
When the molds 1 and 2 are located in a fully closed
position as shown in FIG. 4, a mold cavity 3 having a size
of 250 mm × 200 mm × 50 mm was defined therebetween. The
distance between the opposing inside walls of the molds 1
and 2, which is indicated as "D" in FIG. 4, provides a
thickness of a molding produced in the mold cavity 3 and
equals 50 mm in the state shown in FIG. 4. After closing
the molds 1 and 2 and drain valves 6 and 7, steam was fed
for 5 seconds through feed valves 4 and 5 each having a Cv
value (indicative of flow rate characteristics thereof) of
18 and an effective cross-sectional area of 320 mm^2 to
warm up the molds. The mold 1 was then displaced relative
to the mold 2 through a length of 1 mm (D was increased to
51 mm). Expanded PP beads were fed to the mold cavity 3
and, thereafter, the molds 1 and 2 were closed again.
While maintaining each of the drain valves 6 and 7 in an

41

open state, the feed valves 4 and 5 were opened to feed
steam into the mold cavity 3 through plenum chambers 1a
and 2a and perforations (not shown) formed in the walls
between the plenum chambers 1a and 2a and the mold cavity
5   3 and to purge the air present between the beads from the
cavity 3. The drain valves 6 and 7 were then closed and
steam at a pressure of 0.8 MPa(G) was fed through the feed
valve 4 to the mold cavity 3 until a pressure lower by
0.04 MPa(G) than a predetermined molding pressure was
10 reached in a pressure detecting line 9 connected to a
pressure detecting device 11 (1st heating step). Next,
while keeping the drain valves 6 and 7 closed, steam at a
pressure of 0.8 MPa(G) was fed through the feed valve 5 to
the mold cavity 3 until a pressure lower by 0.02 MPa(G)
15 than the predetermined molding pressure was reached in a
pressure detecting line 10 connected to a pressure
detecting device 11 (2nd heating step). A total process
time in the 1st and 2nd heating steps was 20 seconds.
Finally, while keeping the drain valves 6 and 7 closed,
20 steam was fed through the feed valves 4 and 5 to the mold
cavity 3 until the predetermined molding pressure was
reached in each of the pressure detecting lines 9 and 10
(3rd, substantive heating step). As soon as the
predetermined molding pressure was reached, the feed
25 valves 4 and 5 were closed and the drain valves 6 and 7
were opened. The molds were then cooled with water until a
surface pressure on the molding of 0.059 MPa(G) was
reached in a pressure detecting line 8 connected to a
pressure detecting device 11. The molding was taken out
30 of the mold cavity 3, aged at 60°C for 24 hours and
allowed to stand in a chamber at 23°C for 14 days.
Thereafter, physical properties of the molding were
measured to give the results shown in Table 3-2.

        The above-mentioned predetermined pressure of the
35 saturated steam was the minimum steam pressure P_{min}

42

(MPa(G)) required for properly fuse-bonding the beads to each other and determined by repeatedly producing moldings at various saturated steam pressures increasing from 0.15 MPa(G) to 0.55 MPa(G) at an interval of 0.01 MPa(G). Thus,

5   at a pressure $(P_{min} - 0.01$ MPa), the beads were incapable of properly fuse-bond together.

In determining the minimum steam pressure P_{min} required for properly fuse-bonding the beads to each other, whether or not the beads were properly bonded to each

10 other was evaluated as follows:
A cut with a depth of 10 mm is formed on one of the two largest sides (250 mm × 200 mm) of a sample of PP molding (size: 250 mm × 200 mm × 50 mm) along a bisecting line perpendicular to the longitudinal direction thereof. The

15 sample is then broken into halves along the cut line by bending. The interface along which the halves have been separated is observed to count a total number C1 of the beads present on the interface and the number C2 of the beads having destroyed cells. When the ratio C2/C1 is at

20 least 0.5, the sample is regarded as having properly fuse-bonded beads. The ratio C2/C1 increases with an increase of the steam pressure. The minimum steam pressure P_{min} is a pressure at which the ratio C2/C1 is at least 0.5. At a pressure of $(P_{min} - 0.01$ MPa), however, the ratio C2/C1 is

25 lower than 0.5 and the beads are incapable of properly fuse-bond together.

The minimum steam pressure P_{min} is shown in Table 3-1 and 3-2.

The DSC analysis for the measurement of the physical

30 properties of the polypropylene resin and the expanded PP beads was carried out using Shimadzu Heat Flux Differential Scanning Calorimeter DSC-50 (manufactured by SHIMADZU corporation). Physical properties of the PP moldings are also shown in Tables 3-1 and 3-2.

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43

Example 8

100 Parts of polypropylene resin selected from those
shown in Table 1 and indicated in Table 3-2 were blended
with 0.05 part of zinc borate powder (cell controlling
5 agent) and the blend was kneaded in an extruder and
extruded into strands. The strands were immediately
introduced in water at 18°C for quenching. The cooled
strands were then cut into particles each having a
length/diameter ratio of about 1.0 and a mean weight of 2
10 mg.

In a 400 liter autoclave, 100 parts of the above
resin particles are dispersed in 120 parts of ion-
exchanged water at 18°C (weight ratio of the resin
particles to water of 0.83:1) together with 0.005 part of
15 sodium dodecylbenzenesulfonate (surfactant), 0.3 part of
kaolin powder (dispersing agent), 0.01 part of aluminum
sulfate powder (dispersion enhancing agent), an organic
peroxide selected from those shown in Table 2 and
indicated in Table 3-2 in an amount shown in Table 3-2.
20 With stirring, the dispersion was heated at an average
heating rate of 3°C per minute to the 1 min half life
temperature Tn (92°C) of the peroxide and maintained at
that temperature for 5 minutes to complete the
decomposition of the peroxide. In this heating stage, the
25 time for which the dispersion was maintained at a
temperature in the range of (Tn - 30°C) to (Tn + 30°C) was
15 minutes. Immediately after the above heat treatment,
100 parts of ion exchange water at 18°C were added to the
dispersion so that the weight ratio of the resin
30 particles to water was reduced to 0.45:1. Then, carbon
dioxide (blowing agent) in an amount shown in 3-2 were
added to the dispersion. The dispersion in the autoclave
was stirred, heated to a temperature lower by 5°C than the
expansion temperature shown in Table 3-2 at an average
35 heating rate of 4°C/min and then maintained at that

44

temperature for 15 min. Thereafter, the temperature was raised to the expansion temperature at an average heating rate of 3°C/min and maintained at that temperature for 15 min. One end of the autoclave was then opened to
5   discharge the dispersion to the atmosphere to obtain expanded PP beads. The discharge was carried out while feeding carbon dioxide gas such that the pressure within the autoclave was maintained at a pressure equal to the pressure in the autoclave immediately before the
10   commencement of the discharge. The expanded PP beads were washed, centrifuged and allowed to stand in the atmosphere at 23°C for 48 hours for aging. The beads were then measured for heat of fusion of a high temperature peak thereof and melting point and high temperature peaks of
15   surface and insides region thereof. Also measured were MFR and apparent density of the beads. The results are summarized in Table 3-2. The expanded PP beads were found to be substantially non-crosslinked (the boiling xylene insoluble content was 0).
20   The expanded PP beads thus obtained were placed in a vessel, to which pressurized air was fed so that the inside pressure of the cells of the beads was increased to a pressure shown in Table 3-2. The beads were then molded in the same manner as that in Example 1 to obtain a foamed
25   PP molding having the properties shown in Table 3-2.

Example 9
100 Parts of polypropylene resin selected from those shown in Table 1 and indicated in Table 3-2 were blended
30   with 0.05 part of zinc borate powder (cell controlling agent) and the blend was kneaded in an extruder and extruded into strands. The strands were immediately introduced in water at 18°C for quenching. The cooled strands were then cut into particles each having a
35   length/diameter ratio of about 1.0 and a mean weight of 2

mg.

In a 400 liter autoclave, 100 parts of the above
resin particles are dispersed in 120 parts of ion-
exchanged water at 18°C (weight ratio of the resin

5   particles to water of 0.83:1) together with 0.005 part of
sodium dodecylbenzenesulfonate (surfactant), 0.4 part of
kaolin powder (dispersing agent), 0.013 part of aluminum
sulfate powder (dispersion enhancing agent), an organic
peroxide selected from those shown in Table 2 and

10   indicated in Table 3-2 in an amount shown in Table 3-2.
With stirring, the dispersion was heated at an average
heating rate of 5°C per minute to 90°C and maintained at
that temperature for 10 minutes to complete the
decomposition of the peroxide. In this heating stage, the

15   time for which the dispersion was maintained at a
temperature in the range of (Tn - 30°C) to (Tn + 30°C) was
15 minutes. Immediately after the above heat treatment,
100 parts of ion exchange water at 18°C were added to the
dispersion so that the weight ratio of the resin

20   particles to water was reduced to 0.45:1. Then, a high
pressure carbon dioxide gas (blowing agent) was charged in
the autoclave until the inside pressure thereof was
stabilized at 0.49 MPa(G). The dispersion in the
autoclave was then stirred, heated to a temperature lower

25   by 5°C than the expansion temperature shown in Table 3-2
at an average heating rate of 5°C/min and maintained at
that temperature for 15 min. Thereafter, the temperature
was raised to a temperature lower by 1°C than the
expansion temperature at an average heating rate of

30   0.16°C/min. Subsequently, while a high pressure carbon
dioxide gas (blowing agent) was charged in the autoclave
until the inside pressure thereof was stabilized at
1.18MPa(G), the temperature was raised to the expansion
temperature at an average heating rate of 0.029°C/min.

35   Then, one end of the autoclave was then opened to

46

discharge the dispersion to the atmosphere to obtain
expanded PP beads. The discharge was carried out while
feeding carbon dioxide gas such that the pressure within
the autoclave was maintained at a pressure equal to the
5   pressure in the autoclave immediately before the
commencement of the discharge. The expanded PP beads were
washed, centrifuged and allowed to stand in the atmosphere
at 23°C for 48 hours for aging. The beads were then
measured for heat of fusion of a high temperature peak
10   thereof and melting point and high temperature peaks of
surface and insides region thereof. Also measured were
MFR and apparent density of the beads. The results are
summarized in Table 3-2. The expanded PP beads were found
to be substantially non-crosslinked (the boiling xylene
15   insoluble content was 0).

The expanded PP beads thus obtained were placed in
an ambient pressure for 48 hours so that the inside
pressure of the cells thereof was equal to the ambient
pressure. The resulting beads were then molded in the
20   manner shown below using a molding device shown in FIG. 4
to obtain a foamed PP molding having the properties shown
in Table 3-2.

The molding device had a male mold 1 and a female
mold 2 adapted to be displaced relative to each other.
25   When the molds 1 and 2 are located in a fully closed
position as shown in FIG. 4, a mold cavity 3 having a size
of 250 mm × 200 mm × 50 mm was defined therebetween. The
distance between the opposing inside walls of the molds 1
and 2, which is indicated as "D" in FIG. 4, provides a
30   thickness of a molding produced in the mold cavity 3 and
equals 50 mm in the state shown in FIG. 4. After closing
the molds 1 and 2 and drain valves 6 and 7, steam was fed
for 5 seconds through feed valves 4 and 5 each having a Cv
value (indicative of flow rate characteristics thereof) of
35   18 and an effective cross-sectional area of 320 mm^2 to

47

warm up the molds. The mold 1 was then displaced relative
to the mold 2 through a length of 10 mm (D was increased
to 60 mm). Expanded PP beads were fed to the mold cavity
3 and, thereafter, the molds 1 and 2 were closed again.

5   While maintaining each of the drain valves 6 and 7 in an
open state, the feed valves 4 and 5 were opened to feed
steam into the mold cavity 3 through plenum chambers 1a
and 2a and perforations (not shown) formed in the walls
between the plenum chambers 1a and 2a and the mold cavity

10   3 and to purge the air present between the beads from the
cavity 3. The drain valves 6 and 7 were then closed and
steam at a pressure of 0.8 MPa(G) was fed through the feed
valve 4 to the mold cavity 3 until a pressure lower by
0.04 MPa(G) than a predetermined molding pressure was

15   reached in a pressure detecting line 9 connected to a
pressure detecting device 11 (1st heating step). Next,
while keeping the drain valves 6 and 7 closed, steam at a
pressure of 0.8 MPa(G) was fed through the feed valve 5 to
the mold cavity 3 until a pressure lower by 0.02 MPa(G)

20   than the predetermined molding pressure was reached in a
pressure detecting line 10 connected to a pressure
detecting device 11 (2nd heating step). Finally, while
keeping the drain valves 6 and 7 closed, steam was fed
through the feed valves 4 and 5 to the mold cavity 3 until

25   the predetermined molding pressure was reached in each of
the pressure detecting lines 9 and 10 (3rd, substantive
heating step). A total process time in the 1st and 2nd
heating steps was 12 seconds, while the 3rd step was
performed for 19 seconds. After the feed valves 4 and 5

30   were closed and the drain valves 6 and 7 were opened, the
molds were cooled with water until a surface pressure on
the molding of 0.059 MPa(G) was reached in a pressure
detecting line 8 connected to a pressure detecting device
11. The molding was taken out of the mold cavity 3, aged

35   at 60°C for 24 hours and allowed to stand in a chamber at

48

23°C for 14 days. Thereafter, physical properties of the
molding were measured to give the results shown in Table
3-2.

In the same manner as described above, foamed PP
5   moldings were produced at various saturated steam
pressures increasing from 0.15 MPa(G) to 0.55 MPa(G) at an
interval of 0.01 MPa(G) to determine the minimum steam
pressure P_{min}. The P_{min} thus determined is shown in Table
3-2. The data of the apparent density and the compression
10   strength of the PP molding of Example 9 shown in Table 3-2
are those of the foamed PP molding obtained at a steam
pressure of 0.41 MPa(G) rather than those at the minimum
steam pressure P_{min}. Although the PP molding obtained at
the minimum steam pressure P_{min} (0.039 MPa(G)) shows good
15   adhesion strength, the appearance of the PP molding was
not satisfactory in that a number of depressions were
formed due to insufficient inflation of the expanded PP
beads. With a steam pressure of 0.41 MPa, on the other
hand, no such depressions were found and the PP molding
20   had good appearance.

Table 3-1

Example			1	2	3	4	5	6
Comparative Example								
Resin particles	No.		1	1	1	1	1	2
	MFR (g/10 min)		10	10	10	10	10	7
Peroxide	No.		1	2	2	2	2	2
	Amount (part)		1	1	1	1	1	1
Expansion temperature (°C)			167.0	167.0	170.0	167.0	166.0	144.5
Amount of carbon dioxide (part)			3	3	2.5	3	5.5	6.5
Apparent density of expanded PP beads (g/L)			87	131	89	87	78	48
Melt of fusion of high temperature peak (J/g)	whole		29.0	51.4	27.1	44.5	47.6	12.1
	surface region		25.2	39.4	21.6	33.7	34.2	9.9
	inside region		32.7	55.7	29.8	50.2	58.6	13.4
Melting point of expanded PP beads (°C)	surface region		161.3	160.8	160.6	160.8	160.8	134.5
	inside region		161.6	161.4	161.3	161.4	161.5	136.2
MFR of expanded PP beads (g/10 min)			30	23	22	24	23	18
Inside pressure of cells (MPa(G))			0.23	0.29	0.16	0.29	0.35	0.12
Minimum steam pressure (MPa(G))			0.48	0.44	0.35	0.38	0.39	0.17
Apparent density of PP molding (g/L)			55	91	58	53	46	31
Apparent density of sample (g/L)			55	93	58	53	46	31
Compression strength (kPa)			570	1480	620	650	540	195

Table 3-2

	Example			Comparative Example				
Example / Comparative Example No.	7	8	9	1	2	3	4	5
Resin particles No.	3	1	3	1	1	1	2	3
MFR (g/10 min)	18	10	19	10	11	10	7	18
Peroxide No.	2	2	2	–	–	–	–	–
Amount (part)	1	0.32	0.32	0	0	0	0	0
Expansion temperature (°C)	165.5	166.0	167.0	167.5	168.0	167.5	145.0	165.5
Amount of carbon dioxide (part)	3	3	1 (*1)	4.5	5	5	7	4
Apparent density of expanded PP beads (g/L)	85	128	125	131	69	83	48	93
Heat of Fusion of high temperature peak (J/g) — whole	39.2	50.8	31.9	56.1	44.9	50.5	12.4	40.8
Heat of Fusion of high temperature peak (J/g) — surface region	20.8	45.9	20.0	51.5	41.6	46.4	11.5	39.4
Heat of Fusion of high temperature peak (J/g) — inside region	45.0	59.6	41.4	58.7	47.8	52.7	12.8	40.8
Melting point of expanded PP beads (°C) — surface region	160.0	160.3	160.3	162.0	161.8	161.9	136.6	161.3
Melting point of expanded PP beads (°C) — inside region	160.6	161.1	160.7	161.5	161.6	161.6	136.2	160.6
MFR of expanded PP beads (g/10 min)	34	34	35	10	11	10	7	18
Inside pressure of cells (MPa(G))	0.19	0.31	0	0.29	0.35	0.29	0.12	0.50
Minimum steam pressure (MPa(G))	0.36	0.44	0.39	0.55	0.55	0.55	0.22	0.55
Apparent density of PP molding (g/L)	54	90	91	91	46	54	31	61
Apparent density of sample (g/L)	53	92	93	91	46	54	31	61
Compression strength (kPa)	640	1460	1410	1359	510	650	195	790

*1: inferred value based on experience

51

In Tables 3-1 and 3-2, the apparent density (g/L) of the expanded PP beads is measured as follows. From the expanded PP beads which have been subjected to the aging, a quantity (0.5 to 10 g and 50 to 90 cm^3) of the beads
5   are arbitrarily selected. After the weight Wa (g) of the selected beads is measured, the beads are immersed in 100 ml of water contained in a graduated measuring cylinder. From the volume increment, apparent volume Va (L) of the beads is determined. The apparent density (g/L) is
10 calculated by dividing the weight Wa (g) of the beads by the apparent volume Va (L) of the beads. In Table 3-1 and 3-2, the symbol "(G)" is affixed to MPa to show that the pressure concerned is a gauge pressure.

In Comparative Examples 1-3 and 5, even when the
15 maximum allowable pressure (0.55 MPa(g)) of the molding device was used, the C2/C1 ratios were 0, 0.16, 0.12 and 0.30, respectively, and lower than 0.5. A higher pressure steam was thus needed to obtain PP moldings having properly fuse-bonded beads.

20   In Tables 3-1 and 3-2, the compression strength was measured as follows. A PP molding was cut without leaving any outer surfaces thereof to obtain a sample having a size of 50 mm × 50 mm × 25 mm. The sample was subjected to compression test in accordance with Japanese Industrial
25 Standard JIS Z0234-1976, A method. Thus, the sample was compressed at 23°C at a loading rate of 10 mm/min until a strain of 55 % was reached to obtain a stress-strain curve. The stress at 50 % strain represents the compression strength.

30   From the results shown in Tables 3-1 and 3-2, it is seen that the expanded PP beads obtained from surface-modified propylene resin particles give PP moldings having good recyclability and high mechanical strength at a relatively low molding temperature.

35   In particular, comparison of Example 2 with

52

Comparative Example 1 shows that they are almost the same
with respect to the apparent density of expanded PP beads,
the heat of fusion of whole expanded PP bead, the apparent
density of PP molding, and the apparent density of a PP
5   molding cut sample. However, the minimum pressure
required for properly fuse-bonding the beads to each other
is more than 0.55 MPa(G) in Comparative Example 1 and 0.44
MPa(G) in the case of Example 2, indicating that the
minimum temperature required for fuse-bonding the expanded
10   PP beads of Example 2 is lower by at least 7°C than that
of Comparative Example 1. Yet, the mechanical strengths
of the PP molding of Example 2 are comparable to those of
Comparative Example 1, as expected from the similar heat
of fusion of the high temperature peaks. of the expanded PP
15   beads of Comparative Example 1 and Example 2.

Comparison of Example 4 with Comparative Example 3
shows that they are almost the same with respect to the
apparent density of expanded PP beads, the heat of fusion
of whole expanded PP bead, the apparent density of PP
20   molding, and the apparent density of a PP molding cut
sample. However, the minimum pressure required for
properly fuse-bonding the beads to each other is more than
0.55 MPa(G) in Comparative Example 3 and 0.38 MPa(G) in
the case of Example 4, indicating that the minimum
25   temperature required for fuse-bonding of the expanded PP
beads of Example 4 is lower by at least 12°C than that of
Comparative Example 3. Yet, the mechanical strengths of
the PP molding of Example 4 are comparable to those of
Comparative Example 3, as expected from the similar heat
30   of fusion of the high temperature peaks of the expanded PP
beads of Comparative Example 3 and Example 4.

Comparison of Example 5 with Comparative Example 2
shows that they are almost the same with respect to the
apparent density of expanded PP beads, the heat of fusion
35   of whole expanded PP bead, the apparent density of PP

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molding, and the apparent density of a PP molding cut
sample. However, the minimum pressure required for
properly fuse-bonding the beads to each other is more than
0.55 MPa(G) in Comparative Example 2 and 0.39 MPa(G) in
5   the case of Example 5, indicating that the minimum
temperature required for fuse-bonding of the expanded PP
beads of Example 5 is lower by at least 11°C than that of
Comparative Example 2. Yet, the mechanical strengths of
the PP molding of Example 5 are comparable to those of
10   Comparative Example 2, as expected from the similar heat
of fusion of the high temperature peaks of the expanded PP
beads of Comparative Example 2 and Example 5.
     Comparison of Example 6 with Comparative Example 4
shows that they are almost the same with respect to the
15   apparent density of expanded PP beads, the heat of fusion
of whole expanded PP bead, the apparent density of PP
molding, and the apparent density of a PP molding cut
sample. However, the minimum pressure required for
properly fuse-bonding the beads to each.other is 0.22
20   MPa(G) in Comparative Example 4 and 0.17 MPa(G) in the
case of Example 6, indicating that the minimum temperature
required for fuse-bonding of the expanded PP beads of
Example 6 is lower by at least 6°C than that of
Comparative Example 4. Yet, the mechanical strengths of
25   the PP molding of Example 6 are comparable to those of
Comparative Example 4, as expected from the similar heat
of fusion of the high temperature peaks of the expanded PP
beads of Comparative Example 4 and Example 6.
     Comparison of Example 1 with Example 3 shows that
30   they are almost the same with respect to the apparent
density of expanded PP beads, the heat of fusion of whole
expanded PP bead, the apparent density of PP molding, and
the apparent density of a PP molding cut sample. However,
the minimum pressure required for properly fuse-bonding
35   the beads to each other is 0.48 MPa(G) in Example 1 and

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0.35 MPa(G) in the case of Example 3, indicating that the minimum temperature required for fuse-bonding of the expanded PP beads of Example 3 is lower by 9°C than that of Example 1. Significant difference in the method of

5   production of expanded PP beads between Examples 1 and 3 is that Example 3 uses a carbonate as an organic peroxide. Thus, the use of a carbonate is desirable for reasons of reduction of minimum temperature for fuse-bonding the expanded PP beads.

10   Comparison of Example 7 with Comparative Example 5 shows that they are almost the same with respect to the apparent density of expanded PP beads and the heat of fusion of whole expanded PP bead. Though these examples differ in the apparent density of PP molding and the

15 apparent density of a PP molding cut sample, such a difference would not hinder fair comparison with respect to minimum pressure required for properly fuse-bonding the beads to each other. Thus, the minimum pressure is more than 0.55 MPa(G) in Comparative Example 5 and 0.36 MPa(G)

20 in the case of Example 7, indicating that the minimum temperature required for fuse-bonding of the expanded PP beads of Example 7 is lower by at least 13°C than that of Comparative Example 5. Higher mechanical strengths of the PP molding of Comparative Example 5 are as expected from

25 the higher heat of fusion of the high temperature peak of the expanded PP beads of Comparative Example 5 and greater apparent density of the PP molding of Comparative Example 5 as compared with those of Example 7.

        The micro differential thermoanalysis (μDTA) of the

30 expanded PP beads obtained in Example 7 and Comparative Example 5 was performed using a micro differential thermoanalysis system ("Type 2990 Micro Thermal Analyzer" of T. A. Instrument, Japan Inc.) at a heating rate of 10°C/sec from 25°C to 200°C. Such μDTA curves are shown

35 in FIG. 3. It was found that the melt initiation

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temperature Pm and the extrapolated melt initiation
temperature Pme were about 131°C and about 135°C,
respectively, in the case of the expanded PP beads of
Example 7, whereas the melt initiation temperature Pnm and
5   the extrapolated melt initiation temperature Pnme were
about 168°C and about 171°C, respectively, in Comparative
Example 5.

Thus, the low melt initiation temperature or the low
extrapolated melt initiation temperature is considered to
10   contribute the reduction of the minimum temperature
required for fuse-bonding the expanded PP beads of Example
7.

As compared with Example 2 in which the surface
modification is carried out with the weight ratio of the
15   resin particles to the dispersing medium (water) of 0.45,
Example 8 in which the particle/water ratio is 0.83 gives
similar results in spite of the fact that the organic
peroxide is used in less amount (0.32 part) in Example 8
than that in Example 2 (1 part). In this connection, the
20   advantage attained in Example 8 is apparent in view of the
fact that the apparent density, heat of fusion (entire)
and inside pressure of cells of the expanded PP beads of
Examples 2 and 8 are similar and that the apparent density
of the PP molding and the cut sample thereof in Examples 2
25   and 8 are similar.

In Example 9, the PP molding is prepared from
expanded PP beads whose inside pressure is equal to the
ambient pressure. Such expanded beads would require the
use of much higher temperature steam in order to obtain a
30   PP molding having good fusion between beads and good
appearance as compared with expanded beads whose cells
have an increased inside pressure. By increasing the
amount of the expanded beads filled in the mold cavity and
by adopting a three-step molding process in which the 1st
35   and 2nd heating steps are conducted for a relatively short

56

period of time and the 3rd, substantive heating step is
carried out for a relatively long period of time, the PP
molding obtained shows both good adhesion between beads
and good appearance even at a low steam pressure of 0.41
5   MPa. The melt initiation temperature Pm and the
extrapolated melt initiation temperature Pme were found to
be about 140°C and about 142°C, respectively,

As described previously, a PP molding is regarded as
having properly fuse-bonded beads, when the ratio C2/C1 is
10   at least 0.5. Table 4 shows relationships between C2/C1
ratios of PP moldings and saturated steam pressures used
for molding. As will be appreciated from the results
shown in Table 4, a slight increase in saturated steam
pressure results in an increase of the C2/C1 ratio, namely
15   increase of the bonding force between beads. A greater
C2/C1 ratio is desirable because the PP molding has a
higher resistance to fracture upon being bent.

Table 4

Example No.	Saturated Steam Pressure (MPa(G))	C2/C1 Ratio
Example 1	0.48	0.51
	0.49	0.65
Example 2	0.44	0.50
	0.45	0.63
Example 3	0.35	0.52
	0.37	0.80
Example 4	0.38	0.50
	0.39	0.60
Example 5	0.39	0.53
	0.41	0.66
Example 6	0.17	0.60
	0.18	0.75
Example 7	0.36	0.54
	0.37	0.60
Example 8	0.44	0.56
	0.45	0.70
Example 9	0.39	0.60
	0.41	0.83
Comparative Example 4	0.22	0.55
	0.23	0.62

Examples 10-14

    100 Parts of polypropylene resin selected from those
shown in Table 5 and indicated in Table 10 were blended
with a sterically hindered amine compound selected from
those shown in Table 6 in an amount shown in Table 10, an
antioxidant selected from those shown in Table 9 in an
amount shown in Table 10, 0.05 part of zinc borate powder
(cell controlling agent) and, optionally, a UV-absorbing
agent shown in Table 7 in an amount shown in Table 10.
The blend was kneaded in an extruder and extruded into
strands. The strands were immediately introduced in water
at 18°C for quenching. The cooled strands were then cut
into particles each having a length/diameter ratio of
about 1.0 and a mean weight of 2 mg.

    In a 5 liter autoclave, 100 parts of the above resin

58

particles are charged together with 300 parts of ion-
exchanged water at 18°C, 0.004 part of sodium
dodecylbenzenesulfonate (surfactant), 0.3 part of kaolin
powder (dispersing agent), 0.01 part of aluminum sulfate

5   powder (dispersion enhancing agent), an organic peroxide
selected from those shown in Table 8 and indicated in
Table 10 in an amount shown in Table 10, and carbon
dioxide (blowing agent) in an amount shown in Table 10.
The mixture in the autoclave was dispersed with stirring

10   and heated to a temperature lower by 5°C than the
expansion temperature shown in Table 10 at an average
heating rate of 2°C/min and then maintained at that
temperature for 15 min. Thereafter, the temperature was
raised to the expansion temperature at an average heating

15   rate of 1.5°C/min and maintained at that temperature for
15 min. One end of the autoclave was then opened to
discharge the dispersion to the atmosphere to obtain
expanded PP beads. The discharge was carried out while
feeding nitrogen gas such that the pressure within the

20   autoclave was maintained at a pressure equal to the
pressure in the autoclave immediately before the
commencement of the discharge. The expanded PP beads were
washed, centrifuged and allowed to stand in the atmosphere
for 48 hours for aging. The beads were then measured for

25   heat of fusion of a high temperature peak thereof and
melting point and high temperature peaks of surface and
insides region thereof. Also measured were MFR and
apparent density of the beads. The results are summarized
in Table 10. The expanded PP beads were found to be

30   substantially non-crosslinked (the boiling xylene
insoluble content was 0).

59

Table 5

Resin No.	Kind of Resin	Glass Transition Point (°C)	Vicat Softening Point (°C)	MFR (g/ 10 min)	Melting Point (°C)
3	Propylene homopolymer	-20	147	18	162
1	Propylene homopolymer	-21	148	8	163
4	Propylene homopolymer	-20	150	30	166

Table 6

Hindered Amine No.	Name	Molecular weight
1	Dimethyl succinate-1-(2-hydroxyethyl)-4-hydroxy-2,2,6,6-tetramethylpiperidine polycondensate	3500
2	Bis(2,2,6,6-tetramethyl-4-piperidyl)sebacate	481
3	Poly[{6-(1,1,3,3-tetramethylbutyl)-imino-1,3,5-triazine-2,4-diyl}{2,2,6,6-tetramethyl-4-piperidyl)imino}hexamethylene{2,2,6,6-tetramethyl-4-piperidyl)imino}]	2500

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Table 7

UV-Absorbing Agent No.	Name	Molecular weight
1	2-(3-t-Butyl-5-methyl-2-hydroxyphenyl)-5-chlorobenzotriazol	316

The molecular weights of the Hindered Amine No. 1
and No. 3 and the UV-Absorbing Agent No. 1 shown in Tables
6 and 7 are each average molecular weight (on polystyrene
10   base) measured by gel permeation chromatography using GPC-
LC3A (manufactured by SHIMADZU corporation) in combination

60

with differential refraction detector RID-4 (manufactured
by SHIMADZU corporation) as follows. A sample compound (10
mg) is dissolved in a 10 ml mixed solvent composed of
tetrahydrofuran, acetonitrile and 10 mmol/L acetic acid   .
5   The solution is loaded on a column (Shim-pack CLC-ODS)
having a diameter of 6 mm and a length of 150 mm.   The
chromatography is carried out at a column temperature of
45°C and an elution rate of 1 ml/min.

10   Table 8

Organic Peroxide No.	Organic Peroxide	1 Hr Half life Temperature (°C)	1 Min Half life Temperature (°C)
2	Bis(4-t-butyl-cyclohexyl) per-oxydicarbonate	58	92

Table 9

Anti-oxidant No.	Name	Molecular weight
1	pentaerythrytyl-tetrakis[3-(3,5-di-t-butyl-4-hydroxyphenyl)propionate]	1178
2	bis(2,4-di-t-butylphenyl)pentaerythrytol-diphosphite	604
3	tris(2,4-di-t-butylphenyl)phosphite	647

15   The expanded PP beads were placed in a vessel, to
which pressurized air was fed so that the inside pressure
of the cells of the beads was increased to a pressure
shown in Table 10.   The beads were then molded in the
same manner as that in Example 1 to obtain a foamed PP
20   moldings having the physical properties shown in Table 10.

Table 10

Example		10	11	12	13	14
Resin particles	No.	3	1	1	4	4
	MFR (g/10min)	18	10	10	30	30
Anti-oxidant	No.	1	1	1	1	1
	Amount (part)	0.03	0.025	0.025	0.1	0.1
	No.	2	3	3	3	3
	Amount (part)	0.02	0.05	0.05	0.05	0.05
Hindered Amine	No.	1	1	1	1	1
	Amount (part)	0.2	0.2	0.07	0.1	0.13
	No.	–	–	2	3	–
	Amount (part)	0	0	0.13	0.1	0
UV-absorber	No.	–	–	–	–	1
	Amount (part)	0	0	0	0	0.07
Peroxide	No.	2	2	2	2	2
	Amount (part)	1	1	1	·1	1
Expansion temp. (°C)		165.0	166.0	166.0	168.0	168.0
Amount of CO_2 (part)		3	3.5	3.5	2.5	2.5
Apparent density of expanded PP beads (g/L)		80	95	85	78	76
Melt of fusion of high temperature peak (J/g)	whole	36.7	41.7	41.0	38.9	39.9
	surface region	23.4	35.3	24.8	35.0	24.6
	inside region	43.5	45.8	45.1	44.7	46.5
MFR (g/10 min) of expanded PP beads		36	23	21	47	50
Inside pressure of cells of expanded PP beads (MPa(G))		0.25	0.39	0.23	0.25	0.32
Minimum steam pressure (MPa(G))		0.39	0.43	0.45	0.41	0.39
Apparent density of PP molding (g/L)		54	63	55	53	54
Compression strength (kPa)		640	795	660	630	650
Weatherability		A	A	A	A	A
Heat resistance		A	A	A	A	A

    In Table 10, weatherability and heat resistance of
5   the foamed PP moldings are tested as follows.

62

Weatherability:

Using High Energy Xenon Weather Meter (Model SC750-WN manufactured by Suga Test Machine Co., Ltd., light source: xenon long life arc lamp, intensity of

5   illumination: 90 W/m^2), a sample is subjected to a weatherability test for 200 hours in accordance with JIS D0205-1987. Evaluation is rated as follows.

A: no resin powder is generated even when the sample is rubbed with finger

10   B: resin powder is generated when the sample is rubbed with finger

Heat resistance:

A test sample is heated in a gear oven at 150°C for 22 hours. Evaluation is rated as follows.

15   A: no resin powder is generated even when the sample is rubbed with finger

B: resin powder is generated when the sample is rubbed with finger

In one aspect, the present invention provides a

20   process for the production of a foam PP molding, in which novel expanded PP beads whose surfaces have been modified with an organic peroxide are filled in a mold cavity and heated to be fuse-bonded together. The molding can be carried out at a significantly reduced temperature as

25   compared with the conventional expanded PP beads. Thus, the process of the present invention can save consumption of thermal energy, reduce the cooling time and improve the productivity. The PP molding produced is substantially non-crosslinked and has good recyclability.

30   Hitherto, expanded PP beads showing a high temperature endothermic peak in DSC curve thereof having high heat of fusion have been used for obtaining high rigidity, high impact strength PP moldings. In this case, a high molding temperature must be unavoidably employed

35   and, hence, a general type molding machine designed to be

63

used at usual pressure cannot be used. In contrast,
according to the present invention, even when the expanded
PP beads used are made of a high melting point
polypropylene resin and have high heat of fusion of high
5   temperature endothermic peak, the foamed PP molding having
high rigidity can be obtained using a low pressure steam
(low temperature steam). This permits the use of the
conventional general-type molding machine. Namely, the
process of the present invention can produce PP moldings
10   having high mechanical strengths and/or light weight at
lower costs.

The foamed PP moldings obtained by the process of
the present invention may be suitably used for various
applications, for example, as core materials for
15   automobile. bumpers and cushioning materials for side doors
of automobiles.

The invention may be embodied in other specific
forms without departing from the spirit or essential
characteristics thereof. The present embodiments are
20   therefore to be considered in all respects as illustrative
and not restrictive, the scope of the invention being
indicated by the appended claims rather than by the
foregoing description, and all the changes which come
within the meaning and range of equivalency of the claims
25   are therefore intended to be embraced therein.

The teachings of Japanese Patent Application No.
2001-336831, filed November 1; 2001, No. 2001-401250,
filed December 28, 2001; and No. 2002-054693, filed
February 28, 2002, inclusive of the specifications, claims
30   and drawings, are hereby incorporated by reference herein.

CLAIMS

1. A process of producing a foamed molding, comprising
the steps of:

5   (a) dispersing substantially non-crosslinked resin
particles of a base resin including a polypropylene resin
in a dispersing medium containing an organic peroxide to
obtain a dispersion;

       (b) maintaining said dispersion at a temperature
10   lower than the melting point of said base resin but
sufficient to decompose said organic peroxide, thereby
obtaining substantially non-crosslinked, surface-modified
resin particles;

       (c) foaming and expanding said non-crosslinked,
15   surface-modified resin particles using a blowing agent to
obtain expanded, substantially non-crosslinked resin
beads;

       (d) filling said expanded resin beads in a mold
cavity;

20   (e) heating said expanded resin beads in said mold
cavity to fuse-bond said expanded resin beads together
into a unitary body; and

       (f) cooling said unitary body.

25   2. A process of producing a foamed molding, comprising
the steps of:

       (a) filling expanded, substantially non-crosslinked
resin beads of a base resin including a polypropylene
resin in a mold cavity, said expanded resin beads having a
30   surface region and an inside region surrounded by said
surface region, wherein each of said surface and inside
regions shows a high temperature endothermic peak, in a
DSC curve thereof, in addition to an intrinsic endothermic
peak located at a lower temperature side of said high
35   temperature peak, and wherein said high temperature

endothermic peaks of said surface region and said inside
region have heat of fusion of Hs and Hi, respectively, and
wherein Hs and Hi have the following relationship:
Hs < 0.86×Hi

5   (b) heating said expanded resin beads in said mold
cavity to fuse-bond said expanded resin beads together
into a unitary body; and

         (c) cooling said unitary body.

10   3. A process of producing a foamed molding, comprising
the steps of:

         (a) filling expanded, substantially non-crosslinked
resin beads of a base resin including a polypropylene
resin in a mold cavity, said expanded resin beads

15   exhibiting a high temperature endothermic peak, in a DSC
curve thereof, in addition to an intrinsic endothermic
peak located at a lower temperature side of said high
temperature peak, each of said expanded beads having a
surface showing a melt initiation temperature not higher

20   than the melting point of said base resin,

         (b) heating said expanded resin beads in said mold
cavity to fuse-bond said expanded resin beads together
into a unitary body; and

         (c) cooling said unitary body.

25

     4. A process of producing a foamed molding, comprising
the steps of:

         (a) filling expanded, substantially non-crosslinked
resin beads of a base resin including a polypropylene

30   resin in a mold cavity, said expanded resin beads
exhibiting a high temperature endothermic peak, in a DSC
curve thereof, in addition to an intrinsic endothermic
peak located at a lower temperature side of said high
temperature peak, each of said expanded beads having a

35   surface having an extrapolated melt initiation temperature,

as measured by micro differential thermoanalysis, not
higher than (Tm + 4°C) where Tm is the melting point of
the base resin,

    (b) heating said expanded resin beads in said mold

5 cavity to fuse-bond said expanded resin beads together
into a unitary body; and

    (c) cooling said unitary body.

    5.   A process as claimed in claim 2, wherein said

10 surface region has a melting point lower than that of said
inside region.

    6.   A process as claimed in claim 1, 3 or 4, wherein
said expanded resin beads have a surface region and an

15 inside region surrounded by said surface region, and
wherein said surface region has a melting point lower than
that of said inside region.

    7.   A process as claimed in any one of claims 1-6,

20 wherein said base resin has a melting point of at least
158°C.

    8.   A process as claimed in any one of claims 1-7,
wherein the heat of fusion of said high temperature

25 endothermic peak ranges from 2 to 70 J/g.

    9.   A process as claimed in any one of claims 1-8,
wherein said expanded resin beads comprise a hindered
amine compound.

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    10. A process for the preparation of expanded resin
beads, comprising the steps of:

    (a) dispersing substantially non-crosslinked resin
particles of a base resin including a polypropylene resin

35 in a dispersing medium containing an organic peroxide to

obtain a first dispersion having a weight ratio of said
resin particles to said dispersing medium of 0.6:1 to
1.3:1;

     (b) maintaining said dispersion at a temperature

5   lower than the melting point of said base resin but
sufficient to decompose said organic peroxide, thereby
obtaining substantially non-crosslinked, surface-modified
resin particles dispersed in said dispersing medium;

     (c) impregnating said surface-modified resin

10 particles with a blowing agent, while maintaining the
weight ratio of said surface-modified resin particles to
said dispersing medium at 0.5 or less, to obtain a second
dispersion; and

     (d) reducing the pressure of said second dispersion

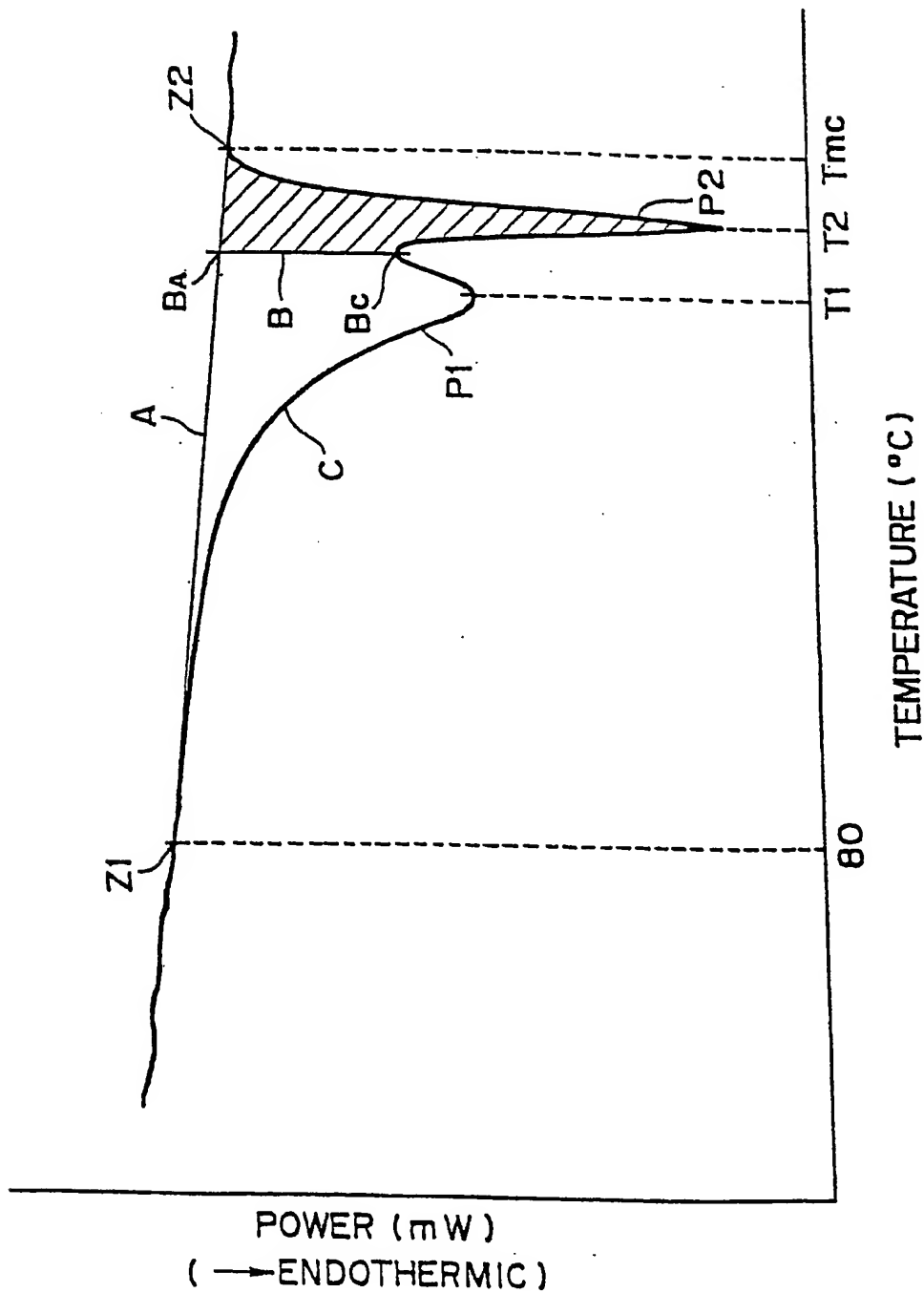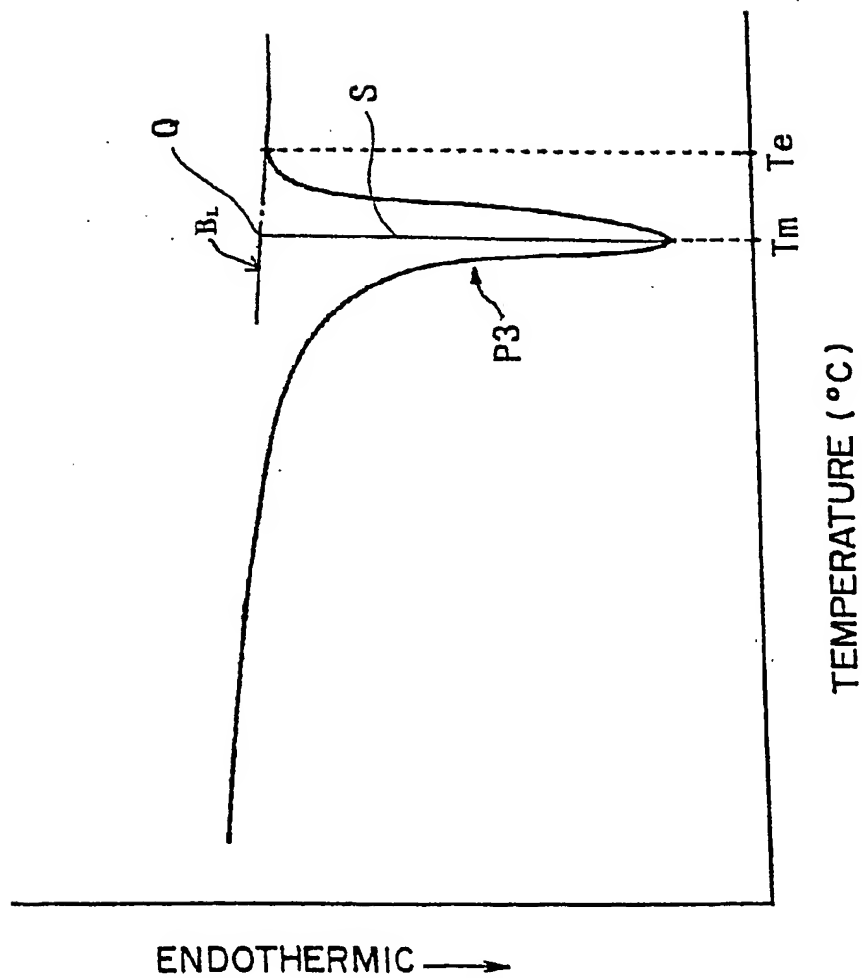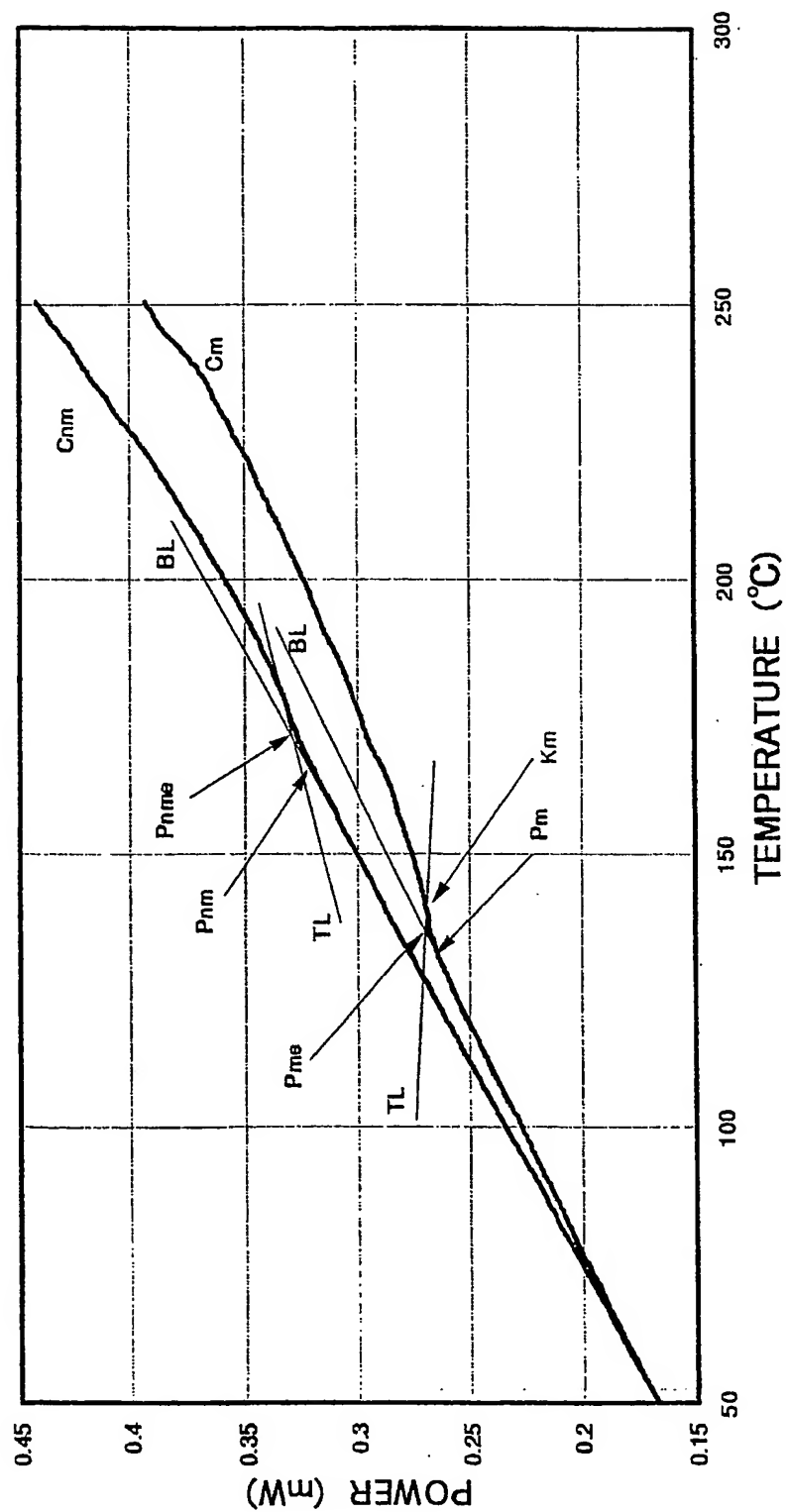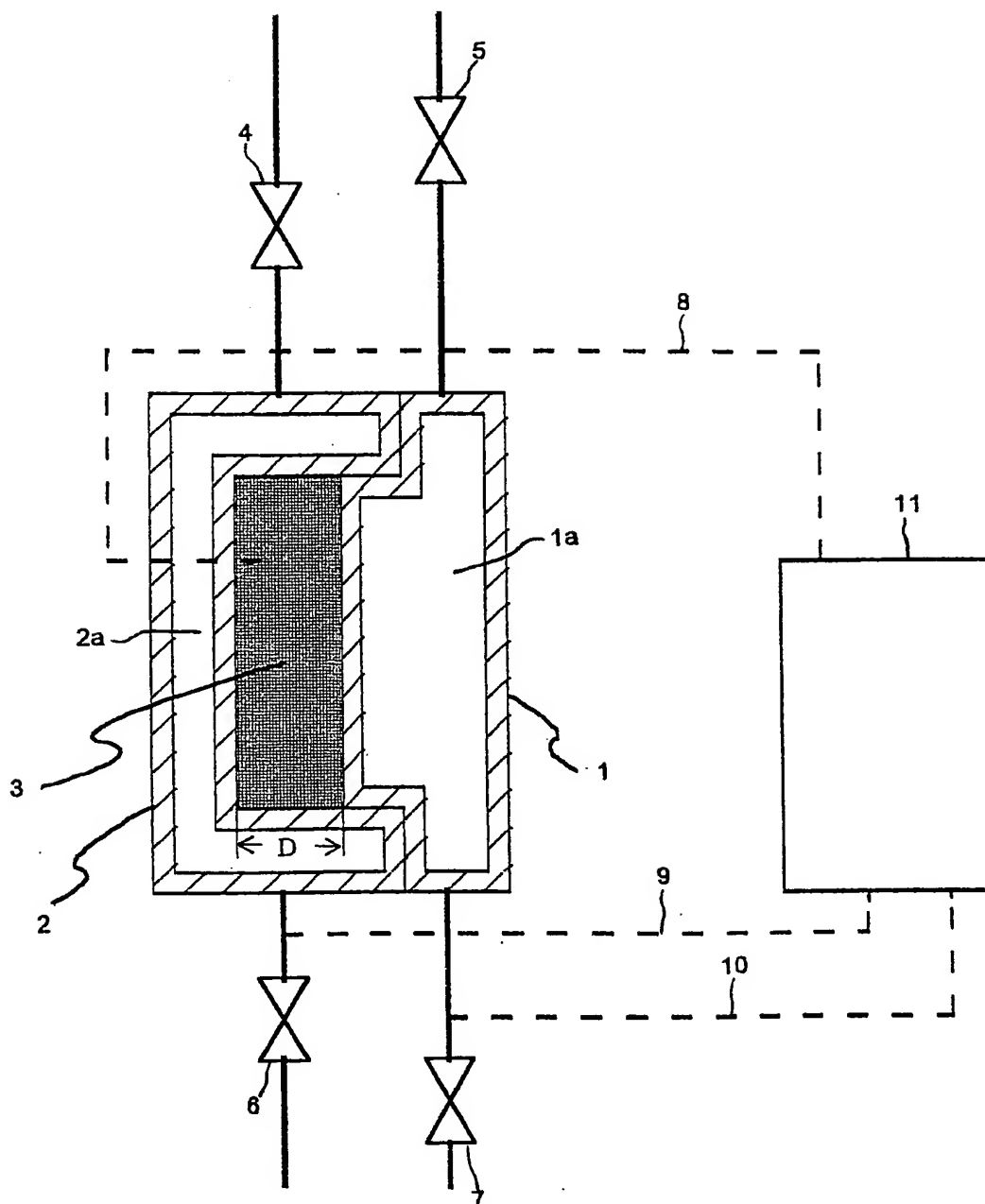15 to foam and expand said surface-modified resin particles.

1 / 5

FIG.1

POWER (mW)

(⟶ENDOTHERMIC)

TEMPERATURE (°C)

FIG.2

FIG.3

FIG.4

FIG.5